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THE SOY BEAN IN AGRICULTURE AND IN COMMERCE

BY

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B. S. University of Illinois, 1921

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN ANIMAL
HUSBANDRY IN THE GRADUATE SCHOOL
OF THE UNIVERSITY
OF ILLINOIS, 1922

URBANA, ILLINOIS

1922
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UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

May 15, 1922.

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Fleming Murray Sherlaw

ENTITLED

THE SOY BEAN IN AGRICULTURE AND IN COMMERCE

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422952

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PART I.

THE SOY BEAN IN AGRICULTURE AND IN COMMERCE.

I. BOTANICAL HISTORY AND CLASSIFICATION.

It is generally conceded that Kämpfer was the first European to make the soy bean known to his countrymen. Following his visit to Japan in 1690-1692, he published "Amoenitatum Exoticarum" in 1712 in which he described the plant giving it the Japanese name, Daidsu Mame. Linnaeus, in his publications, gave to it the formal name of Dolichos soja. This name was first used in 1753. In 1794, Moench rechristened the Linnaean plant Soja hispida and sixty years later, 1856, Maximowicz gave to it the name Glycine hispida, a title which has been very generally adopted.

Siebold and Zuccarini had previously, in 1834, called a Japanese plant Glycine soja taking for granted that it was the Dolichos soja of Linnaeus. However, this was not the soy bean cultivated by the Japanese but a wild form which was later classified by Regel and Mack as Glycine ussuriensis.

Under present day botanical rules the soy bean, which is known only in the cultivated form, is called Glycine hispida after Maximowicz, and its nearest relative, Glycine ussuriensis or Glycine soja. The two forms are fundamentally very similar, the principal distinction being that Glycine soja, the wild form, has more slender and more twining stems, is less hairy, bears smaller pods and seeds and has smaller flowers than than does the cultivated form, Glycine hispida.

II. HISTORY AND DEVELOPMENT.

It has been definitely established that the soy bean was an important food with the Chinese and Japanese as early as 2500 B.C. When China first opened her doors to World trade, the internal commerce in soy beans and soy bean products had been long established and was a very flourishing industry. Even today, in value and in extent and variety of uses, the soy bean is far and away the most important legume grown in Asiatic countries. In addition to using considerable quantities as human food, the Asiatic peoples utilize relatively large quantities by extracting the oil and using the residue or cake for stock feed and for fertilizing purposes.

It was not until near the close of the 18th Century that the soy bean found its way to Europe, the first recorded European cultivation of the plant being in 1790. For almost a century the plant remained more or less of a botanical curiosity to Europeans, and not until 1875 did Professor Haberlandt, an Austrian, begin his work with the soy bean. As a result of his investigations, he strongly recommended its use as a food for both man and beast. However, the plant failed to become the success that the experimenter hoped it would, although there had been considerable interest aroused by his work.

Americans were not as slow in recognizing the worth of the soy bean as were their European neighbors. While Europe still looked on the plant as a curiosity, certain American citizens were busily engaged in cultivating the plant and using some of its products for human food. Thomas Nuttall, writing in the "New England Farmer" of October 23,1829, is the first person to

mention the soy bean in American literature. He had been growing a red-flowered variety with chocalate-brown seeds and he remarked in his article that its principal use was for preparing "the well-known sauce, soy, which is at this time only prepared in China and Japan". In the same journal of November 23,1831 there appeared an account of the successful culture of the plant by a gentleman in Milton, Massachusetts from seed obtained from Mr. Nuttall.

The next written account appeared in 1853 when a Mr. A.H. Ernst of Cincinnati, Ohio wrote about the "Japan Pea". He says in part, "This plant is stated to be of Japan origin, having been brought to San Francisco about three years since, and thence into Illinois and Ohio". In 1854 the Perry Expedition to Japan brought back two varieties of "soja bean" common to that country. At this time the United States Department of Agriculture became interested in the plant and, through the Commissioner of Patents, distributed samples of the "Japan Pea" and the Perry "soja bean" throughout the country. References to the plant in various periodicals became more and more frequent from that time on.

Since 1890, experiments with the soy bean have been undertaken by various agricultural experiment stations and considerable space has been occupied in bulletins dealing partly or wholly with the soy bean. At first, the work dealt almost entirely with studies of varieties, climatic requirements, and methods of cultivation. Later, when the value of the plant as a stock feed became apparent, the majority of the work was along that line. A still later development brought about studies of its value as an article of the human diet. In the stock feeding

field, the greatest amount of work has been done with hogs, perhaps because of the rapidity with which results are obtainable and because of the necessity of feeding hogs large amounts of concentrated feeds. There has been very little done on the feeding of soy beans to beef and dairy cattle, while practically nothing has been done with horses, sheep and poultry. Feeding experiments involving soy beans have not yet covered all the important problems, even with hogs, while there is a very wide field for investigation among the other classes of livestock.

Prior to the Russo-Japanese war, China and Japan were the largest producers of the soy bean and its products, while they were also the largest consumers. During this war, production was greatly stimulated throughout Manchuria and with the cessation of hostilities it became necessary to develope a market for the surplus. With this end in view, trial shipments were made to Europe, but these early attempts to introduce the soy bean to European markets all failed because of improper methods of shipping which resulted in the deterioration of the beans. The shipments were in such bad condition when they arrived that they were unfit for use.

About 1908, improvements in shipping methods were so perfected that a successful trial shipment arrived at the English oil mills in good condition. Such good results were obtained from the crushing and oil extracting processes that larger imports were immediately made. This successful importation and the successful utilization of the soy bean oil and cake led to greater importations, not only to England but to the Continent as well, and the importations of soy beans from Manchuria and Japan soon

reached enormous proportions. As the value of the oil and cake came to be better realized, new uses and new markets were developed and the soy bean trade between Europe and the Orient assumed such large proportions that the soy bean became a leading competitor of other oil bearing seeds.

The soy bean was first utilized for oil and meal production in the United States by a mill on the Pacific coast about 1910. The beans used had been imported from Manchuria and the success of the venture is amply demonstrated by the constantly increasing importations of Manchurian beans and the increasing production of soy bean oil and meal or cake. The first American grown seed to be crushed was in 1915; a mill in North Carolina using some locally grown beans. However, the crushing of domestic beans has not increased in proportion to the increase in production of the beans, primarily because of the prevailing high prices obtainable for seed beans. This demand for soy bean seed has led many farmers, who otherwise would be uninterested, to grow the plant and thus to realize the value of the soy bean in improving their own land.

III. DISTRIBUTION.

In the Orient, soy beans are grown extensively in Japan, Korea and Manchuria and in some of the northern Chinese provinces, notably Shan-tung and Shan-si. Southern China doesnot produce the soy bean in quantity although the United States Department of Agriculture has received plants from Canton and Hongkong in that region. The soy bean is also grown in Java, Formosa, Cochin-China and India. Watt says[1] that the soy bean is quite extensively grown throughout India, and in the Khasi Hills, the Naga Hills, Eastern Bengal and Burma is often found as a weed. The few varieties which have come to the United States from India are quite distinct, a fact which seems to imply long culture by the natives.

Soy beans have been grown in every state in the Union, although they have not been equally successful in every state. They are very well adapted to a considerable range of climate but they do best in localities suited to corn. Thus, in this country, they will do well in the region from the states immediately north of the Gulf states to the northernmost limits of corn growing and from Ohio on the east to Nebraska and Kansas on the west. At the present time this region, more commonly known as the Corn Belt, together with some of the Southern states, produces the bulk of the soy beans grown in the United States.

Europe produces very few soy beans. There are probably not more than ten varieties grown in Germany, France, Austria and Italy. These varieties are Etampes or Ito San, Samarow, Yellow Riesen or Mammoth, Chernie, Yellow, Butterball

1. The Dictionary of the Economic Products of India.

or Giant Yellow, Brown or Ogemaw, Early Black of Podolia or Buckshot and #5039 or Wisconsin Black.

IV. SOME IMPORTANT VARIETIES IN THE UNITED STATES.

Before the United States Department of Agriculture began its numerous importations of soy beans about 1898, there were not more than eight varieties grown in this country. These were, Ito San, Mammoth and Butterball with yellow seeds; Kingston and Buckshot with black seeds; Eda and Ogemaw with brown seeds; and Guelph with green seeds. These early varieties were known also by such names as Late Yellow, Medium Green and Early Black, one adjective referring to the time of maturity and the other to the seed color. While there were only a few varieties to classify, this system of nomenclature was satisfactory, but as the number of varieties increased it became inadequate. In 1907, when twenty-three soy bean varieties were recognized in this country, Ball created a single name system.

At the present time there are about three hundred varieties in the United States. Obviously, the task of creating distinctive names for all these would be tremendous, so the United States Department of Agriculture has simply numbered them, allowing the more important varieties to retain their names. For example, #17251 is Buckshot, #17268 is Ito San, etc.

In establishing and describing the different varieties the following characteristics were used:

1. Habit of growth.
2. Foliage.
3. Pubescence.
4. Flowers.
5. Pods.
6. Seeds.

The varieties described below are among the most popular and most prominent varieties grown in the United States at the present time.

Very early maturing- #17258 or Ogemaw.
Plants stout, erect, bushy; height 18 to 22 inches; pubescence tawny; flowers white; pods large, 2 to 2 1/4 inches long, tumid, crowded, shattering badly; seeds deep brown, large, 8 1/2 to 9 mm.long,eliptical, much flattened; hilum pale; germ yellow.

Early maturing- #25161 or Early Brown.
Plants stout, erect, bushy; height 18 to 24 inches; pubescence tawny; flowers purple; pods medium size, 2 to 2 1/8 inches long, tumid,half crowded, shattering little; seeds brown, medium sized, 7 1/2 to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Except for color of seeds and maturity, this variety is difficult to distinguish from Ito San, #17268.

Medium early maturing- #17261 or Guelph; #20406 or Elton.
Guelph- Plants stout, erect, bushy; height 20 to 24 inches; pubescence tawny; flowers purple; pods medium size, 1 1/2 to 1 3/4 inches long, tumid,half crowded, shattering much; seeds chromium green, medium sized, 7 to 8 mm. long, elliptical, slightly flattened; hilum brown; germ green.
Elton- Plants stout, erect, bushy; height 28 to 32 inches; pubescence both gray and tawny; flowers purple; pods medium large, 1 3/4 to 2 inches long, compressed, half crowded, shattering little; seeds straw yellow, medium sized, 7 1/2 to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow.

Medium maturing- #17268 or Ito San; #17269 or Med.Yellow.
Ito San- Plants stout, erect, bushy; height 18 to 22 inches; pubescence tawny; flowers purple; pods medium size, 1 1/2 to 1 3/4 inches long, tumid, half crowded, shattering moderately; seeds straw yellow, medium size, 7 1/2 to 8 mm. long, elliptical, slightly flattened; hilum pale, a brown speck at the micropylar end; germ yellow.
Medium Yellow- Plants stout, erect, bushy; height 30 to 36 inches; pubescence tawny; flowers both purple and white; pods medium size, 1 1/2 to 1 3/4 inches long, tumid, half crowded, shattering moderately; seeds straw yellow, medium size, 7 to 7 1/2 mm. long, elliptical, slightly flattened; hilum pale; germ yellow.

Medium late maturing- #17254 or Ebony; #17271 or Haberlandt; #17273 or Butterball.
Ebony- Plants stout, erect, bushy; height 22 to 26 inches; pubescence tawny; flowers purple; pods medium size, 1 1/2 to 1 3/4 inches long, half crowded, shattering moderately; seeds black, medium small, 7 to 7 1/2 mm. long, oblong, much flattened; hilum pale; germ yellow.

Haberlandt- Plants stout, erect, bushy; height 24 to 30 inches; pubescence tawny; flowers both purple and white; pods crowded, medium size, 1 3/4 to 2 inches long, tumid, shattering little; seeds straw yellow, medium large, 8 to 8 1/2 mm. long, elliptical, slightly flattened; hilum brown; germ yellow.
Butterball- Plants stout, erect, bushy; height 18 to 24 inches; pubescence gray; flowers white; pods medium size, 1 1/2 to 2 inches long, tumid, half crowded, shattering little; seeds straw yellow, medium size, 7 1/2 to 8 mm. long, elliptical, slightly flattened, hilum light brown; germ yellow.

Late maturing- #17278 or Hollybrook; #17280 or Mammoth.
Hollybrook- Plants stout, erect, bushy; height 24 to 30 inches; pubescence gray; flowers both purple and white; pods medium size, 1 1/2 to 1 3/4 inches long, tumid, crowded, shattering little; seeds straw yellow, small to medium size, 5 1/2 to 6 1/2 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow.
Mammoth- Plants stout, erect, bushy; height 36 to 42 inches; pubescence gray; flowers white; pods medium size, 1 1/2 to 1 3/4 inches long, scattered, shattering little; seeds straw yellow, medium small size, 6 1/2 to 7 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. This is the standard commercial late variety, more extensively grown at present than any other.

V. CLIMATE AND SOIL REQUIREMENTS.

As has been stated before, soy beans are very well adapted to a considerable range of climate. They are especially well adapted to the cotton districts of the South and as far north as the Ohio and Potomac rivers. In this general region, the later varieties with heavy yields can be successfully cultivated. Some of the earlier maturing varieties are able to produce profitable yields of seed in the states north of the Ohio and Potomac dividing line, while the later varieties may be used as hay or for forage purposes. The map on Page 12 shows the areas of the United States to which different varieties of the soy bean are best adapted with respect to climatic conditions.

Key to Map.

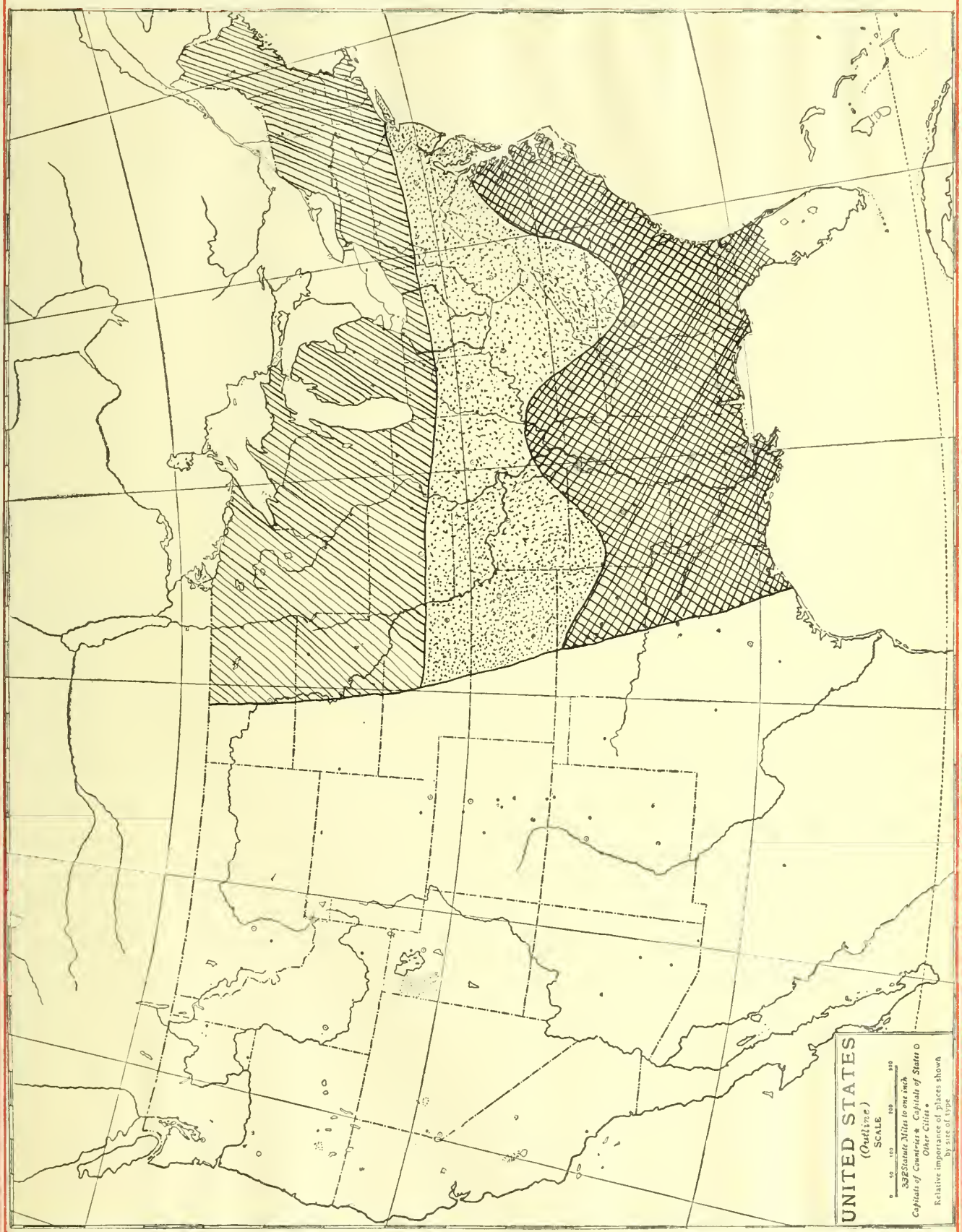
The later and larger varieties for seed production.

Medium and medium-late varieties for seed and the same varieties and later varieties for forage.

Very early varieties for grain production and the medium and medium-late varieties for forage.

Under the extreme heat of the Southwest and of the southern portions of the Gulf states, the soy bean pods often fail to fill, although a good growth of forage is obtained. Soy beans are very drought resistant and will also withstand an excess of moisture better than either alfalfa or clover.

As in its adaptability to climatic conditions, the soy bean can also make a growth on almost any type of soil. However, it succeeds best on fertile clay or sandy loam. For this reason it is particularly suited to the "black dirt" of the



Adapted from U.S.D.A. Farmer's Bulletin # 973.

Corn Belt. However, they will make a growth on soil too poor to produce even a fair yield of corn, provided that they are properly innoculated. Rather extensive experiments with the plant have been carried on by the Wisconsin Experiment Station on some of the light sandy soils of that state. They report[1] that, "Exceedingly favorable results have been secured ....which lead us to believe that soy beans will become a staple crop on our light, sandy soils".

Altho the soy bean will grow on wet soils, a well-drained soil is greatly to its advantage, and notwithstanding the fact that it will grow on soil too acid for clover, a good application of ground limestone to acid soil will result in a much better stand. In fact, the addition of lime has been found to greatly increase the yield of soy beans on every occasion.

It is not as necessary that fertilizers be applied for soy beans as it is that the seed be innoculated. Certainly, it is entirely useless to apply nitrogenous fertilizers as the beans will gather all they need, and also a surplus for storage in the root nodules, from the free nitrogen of the air. However, a good application of phosphorus, either in the form of acid phosphate or raw rock phosphate, together with wood ashes or muriate of potash, will give the best results where a fertilizer is needed. The rate of application of these fertilizers is 300 pounds of acid phosphate and 250 pounds of wood ashes or 25 pounds of muriate of potash per acre. In following corn which has been properly phosphated, it is unnecessary to fertilize for soy beans.

1. Wisconsin Bulletin No. 116.

The seed-bed for soy beans is prepared just as is that for corn. After an early, deep plowing the land should be harrowed regularly until the beans are planted. Unless this is done, the young beans are apt to be crowded out by weeds. The upper two inches of the seed-bed should be finely pulverized and mellow, while the soil below should be well firmed. It will be found that the the soy beans will respond readily to any extra care given the seed-bed.

In common with the other legumes, soy beans must be innoculated when they are planted in a new field if a satisfactory stand is to be secured. They will make a fairly good growth on rich soil without innoculation but it will be at the expense of the nitrogen already in the soil as the plant will not gather nitrogen from the air unless bacteria are located on its roots. There are two principal methods of innoculation practiced today. The first is the so-called "glue method", first suggested by the Illinois Experiment Station, which is in all probability the most effective and certainly the simplest and least expensive. In this operation, the seed beans are slightly moistened by sprinkling with a dilute solution of glue in warm water (six ounces of glue to one gallon of water). After the beans are thoroughly moistened, they are dusted with soil taken from a field where soy bean plants have previously developed nodules. The beans should be turned with a shovel several times during the moistening and dusting to make certain that every bean is brought into contact with the glue water and soil. They should then be spread out to dry in a shady spot, never in the direct rays of the sun as this would kill the bacteria.

The advantages of this method are that bacteria are brought into intimate contact with every seed, where they will be in an excellent position to reach the roots when growth starts; that less soil is required; and that less labor is required to innoculate the beans.

The second method consists of drilling in with the beans at the time of seeding about 100 pounds of infected soil per acre. A third method is sometimes used, that of innoculating with a pure culture, obtainable from commercial firms or from the United States Department of Agriculture, but this method has not always proved as satisfactory as the two above mentioned. When once the bacteria are thoroughly established in the soil, further innoculation will not be necessary as the organisms will live until the next soy bean crop is planted, assuming that the crop is used in a regular three or four year rotation. Soy beans are not cross-innoculated by bacteria from other legumes so far as is known at present.

VI. GROWING AND HARVESTING. (CULTURE).

After the seed-bed has been properly prepared and the seed itself innoculated, we may proceed with the planting. This procedure may be divided into three principal steps, viz: time of planting, rate of seeding, and method of seeding.

The time of planting soy bean seed depends upon two things, the use to which the crop is to be put and the latitude. Of course, weather conditions must be considered just as with any crop. In general, soy beans sown for grain must be planted earlier than those sown for forage. The most favorable time, if grain is desired, is immediately following corn when the ground has become thoroughly warmed. This time is also good if the soy beans are to furnish the main hay crop. Care must be taken that there are likely to be no more frosts because the bean seedlings are easily injured by spring frosts. Furthermore, early plantings in cool weather require a longer time to mature and the seedlings come through the ground more slowly. In case their growth is checked by cold or frost, weeds are likely to get a start on them and cut down the yield considerably. As a green manure or pasture crop, the soy bean may be sown as late as July first in the Corn Belt and in the southern states its planting may be delayed until August first.

Of course, the further north one goes, the earlier must a given variety be planted if it is to mature its seeds. Some varieties such as Ebony, Butterball and Mammoth which are late maturing in habit, will fail to mature altogether when planted in the more northern states. This is to be expected,

however, and the early maturing varieties only used in higher latitudes.

The rate of seeding soy beans also depends upon the use to which the crop is to be put. For hay, a dense stand is desirable and consequently close drilling of the seed is the proper method. When seed is the object in view, the plants must be given more room and provision must be made for cultivating the crop. Another factor influencing the rate of seeding is the size of the seed, as it is obvious that a bushel or a pound of Hollybrook seed will contain fewer beans than a like amount of the smaller Ebony. The amounts referred to below are based on a medium sized seed such as Ito San or Guelph and estimates as to the proper amounts of larger or smaller seeds may be easily made.

In planting for hay, one has the choice of drilling in solid, that is with every hoe in the grain drill in operation, or drilling in rows from 28 to 36 inches apart. The first method will give a heavier yield and the stems will be of finer quality. However, the hay will be more weedy if the seeds are drilled in solid than it will if space is left for cultivation. When drilled solid, an acre will require from five to six pecks of seed, while if the rows are from 28 to 32 inches apart, very good results will be obtained with three pecks per acre.

In growing soy beans for seed, cultivation is of course necessary. If the rows are spaced 28 to 32 inches apart, a one horse cultivator must be employed, so that if any considerable acreage is to be grown, it is advisable to put the rows from 34

to 36 inches apart so that a two-horse machine may be used and more economical cultivation practiced.

The ordinary grain drill is perhaps the best means of putting in the seed. The feed cups not in use may be covered up and any desired spacing obtained. The oats feed should not be used as there is some trouble from splitting of the seed when it is used. As most of the later type corn planters have special attachments to be used in planting beans, they may be employed instead of a grain drill. Whatever the means, the machine should be adjusted to plant the beans about three inches apart and rather shallowly. In heavy loam soils, one inch is deep enough as a heavy rain will form a crust and prevent the beans from coming up. In lighter sandy soils or light loams the beans may be put about two inches below the surface, while, in case they are put in during a dry spell, it may be well to plant them as deep as three inches to insure them sufficient moisture. Deep planting is rather risky because of the chance that a rain will form a crust and the beans will "break their necks" trying to get through. If such a crust is formed, it is sometimes possible to break it by going over the field with a smoothing harrow or a weeder. However, such a procedure is dangerous to the tender seedlings and should be avoided by shallow planting.

Soy beans respond readily to cultivation and as a rule require about the same number of cultivations as corn. As it is necessary in harvesting to cut quite close to the ground, all cultivations should be shallow and level because rough, ridged cultivation interferes seriously with the harvesting machinery. If the soy beans have been drilled solid, it is possible to

cultivate only once after the beans are out of the ground. This should be done when the plants are about three inches tall by running a weeder across the rows. This operation should be performed during the hottest part of the day while the seedlings are tough, else many of them are apt to be broken off. Cultivation of soy beans planted in rows may be done just as is that of corn and, preferably, as often as corn is cultivated.

In cutting soy beans for hay, better quality will be obtained if they are harvested when the seeds are well formed in the pods. However, they may be cut with success at any time from the setting of the seed until the leaves turn yellow. If cutting is delayed too long, the stems rapidly become woody and unpalatable and decrease considerably in feeding value. They may be cut with a mower and a rake, just as ordinary hay. It is best to cut them when the dew is off, and leave them until well wilted before raking into windrow or cock. They should be left this way for a day or two, depending on the weather, and then placed in small stacks. If properly put up, these stacks will turn water readily. Four or five days of fair weather is ample time to properly cure soy bean hay. Before hauling to the barn or stack, the small shocks or stacks should be opened up for an hour or two. It is essential that the stems be well cured before storing or the hay will surely heat and spoil.

A good deal of care is necessary in cutting soy beans for seed as no other crop shatters so easily. Most varieties should stand until nearly mature, or until most of the leaves have fallen. In the easily shattered varieties such as Guelph, the cutting should be done when about one-half of the leaves have

fallen. Some shattering may be avoided if the cutting is done on a moist, cloudy day or while the dew is still on the plants. The machine most commonly used is a mower with a side-delivery attachment. All handling after cutting such as bunching and shocking should be done on a cloudy day if possible to reduce shattering. It is best to thresh the beans in the field as it involves less handling than threshing from the stack or barn. The ordinary grain thresher cracks a good many beans even though the cylinder speed is reduced, although if the beans are in good condition and the operator careful and experienced, very good results may be obtained. However, a grower of soy beans who intends to stay in the business permanently will find it profitable to secure a special pea and bean separator.

When storing the threshed beans, care must be taken that they are not kept in large quantities until they are thoroughly dry. If the beans are not put in bins over three feet deep and are carefully watched until completely dried out, no trouble is likely to occur. If heating does take place, the germination is apt to be seriously injured if not destroyed.

The attempts to use soy beans alone as silage have been rather unsuccessful, but when mixed with corn the resulting silage is a valuable feed. The crops are grown either in separate fields or together, being planted in the ratio of two parts corn to one part soy bean seed. This method, however, is rather unfavorable to the soy beans as the corn tends to crowd them out. Better yields of soy beans are obtained when they are grown apart from the corn. When filling the silo, the usual practice is to

use two loads of corn to one of soy beans, mixing them as they go through the cutter.

The beans are best harvested for silage when the seeds are about half-grown. They are more easily handled at this time and there is less waste. If a binder is used in harvesting them for silage, waste is still further reduced and the crop is much more easily handled both in the field and at the cutter.

VII. PLACE IN A CORN BELT ROTATION.

The soy bean is particularly adapted to various systems of crop rotations. It may take a regular place in a rotation; it may be used as a substitute for clover when the latter kills out; and it may be used as a catch crop or as an orchard cover crop. As a cover crop, it is very valuable as it will produce a large amount of fall pasturage or green manure for plowing under on soils lacking in organic matter. One of its important uses is in substituting for grass or clover, where it is necessary to secure an annual crop producing plenty of high quality hay in a hurry. Soy beans are particularly valuable as a substitute for clover for two reasons, first, because they are actually superior to clover in feeding value, and second, from the standpoint of maintaining soil fertility, it is much better to substitute a legume where a legume has failed than to substitute a grass, thus giving the entire rotation period to the grass family which is notoriously exhausting to the nitrogen of the soil.

In a typical four year Corn Belt rotation of corn, oats, wheat and clover, soy beans fit in admirably in place of oats. When soy beans are put into the rotation, the hard fall plowing for wheat is done away with as the soy beans leave the soil in an ideal condition, especially if the weeds have been kept out. At times the wheat will be benefitted if the soil is disked before the wheat is put in, although in the majority of instances even this may be dispensed with.

In case hay is not needed, another soy bean crop may replace the clover and thus give two cash crops of value as, at

the present time, soy bean seed is rather high in price. The legumes coming between the cereals minimize the cost of maintaining the fertility of the soil. If normal amounts of manure are applied to the soil, the legumes will supply the remainder of the nitrogen and organic matter, making it necessary to purchase only the mineral elements of plant food.

It has long been known that potatoes after corn, followed by wheat are very favorable to the wheat. Wheat following oats does better, as a general rule, than when following corn because the early harvesting of the oats leaves plenty of time to prepare a good seed-bed for the wheat, something impossible of accomplishment if corn immediately precedes wheat. Soy beans, although occupying the land until late in the season, furnish a seed-bed at least equal, if not superior, to that prepared after potatoes and oats. Work done at the Ohio Experiment Station shows that this is the case.[1]

TABLE SHOWING AVERAGE YIELDS OF
WHEAT (IN BUSHELS PER ACRE)
FOLLOWING VARIOUS CROPS.

AFTER SOY BEANS	AFTER POTATOES	AFTER OATS	AFTER CORN
38.51	38.17	37.24	28.21

It seems very significant that wheat after soy beans averages ten bushels per acre more than it does after corn; 1.27 bushels more than after oats; and a fraction better than after potatoes, long recognized as a very favorable crop to precede wheat. These results are very well borne out by results

1. Ohio Bulletin No. 312.

obtained on many Corn Belt farms. The fact that steadily increasing numbers of farmers are putting in soy beans after their corn in a four year rotation is evidence that the value of the crop is becoming more apparent every year.

Indeed, when one considers the beneficial effect of the soy bean on the tilth of heavy soils, its power to gather nitrogen from the air, and the large amount of organic matter it is capable of producing, to say nothing of its value as a human and a stock food and its uses in the commercial world, it is not surprising that the annual acreage is increasing year by year. It is safe to state that before many years pass by, the soy bean will really come into its own and approach to a greater degree, in this country, the high place it holds in the Orient as an economic factor in human affairs.

PART II.

I. INTRODUCTION.

In view of the recent exceedingly high prices obtaining for commercial concentrated feeds of a nitrogenous nature, it has become imperative that the producer and feeder of livestock, especially in the Corn Belt, find a cheaper source of protein to supplement his corn. The producer of market animals must of necessity operate on a narrower margin than the producer of pure-bred breeding stock and consequently the difference in cost of nitrogenous supplements often means the difference between profit and loss on a given lot of animals. The pure-bred breeder can afford to pay more for his concentrated feeds because his animals sell for more individually. Nevertheless, the saving in cost of feed is equally as great in dollars and cents, altho not as great proportionally, to the pure-bred breeder as to the feeder of market animals.

In attempting to lower the cost of production, feeders and breeders have cut down on the supplementary ration, have used cheaper, lower grades of nitrogenous concentrates and by various and sundry doubtful practices attempted to produce live-stock at a profit. The two methods of reducing cost mentioned above are at best doubtful. Either method results in slower growing and more poorly finished animals. Slower growth means slower turnover with greater interest charges and more labor costs. Animals below the best finish of course bring lower prices on the market. In general, the feeder who has fed the best quality obtainable and who has practiced rigid economy in other directions has been better off in recent years.

It is a well known economic fact that the best farm

practice demands that as far as possible, all feeds consumed on the farm be produced there. A feeder of livestock will make more profit from his feeding operations if he can produce the necessary feeds on his own land. The principal obstacle to overcome in this system is the production of a suitable concentrated protein feed. If it is feasible to economically produce such a feed in the Corn Belt, it will be extremely desirable. Heretofore, the purchase of tankage, cottonseed meal, linseed meal or any of the other commercial concentrated feeds has worked a hardship on the farmer. At present there seems to be a possibility that the feeder need no longer be handicapped by the high cost of protein supplements.

There is no other feed that can be grown on the farm that is the equal of the soy bean in protein content. There is no other crop that combines this high protein content with such beneficial effects on the soil, such a high oil content, such value as hay or as a soiling crop, such adaptability to a wide range of climatic and soil requirements and such an ability to fit into almost any system of crop rotation. These factors combine to make the soy bean preeminently the crop to use in the production of a protein concentrate on the farm. To date, they have been little used in feeding livestock. This is primarily due to the demand for seed beans which has made the crop so high priced that the farmer could better sell the soy beans and purchase his concentrated feeds. Another factor in keeping up the price has been the demand for beans by the producers of soy bean oil. The demand for this oil is quite strong as the thousands of tons of soy beans and soy bean oil imported annually will show.

Experiments with soy beans as a food for livestock are a rather recent development and are still in progress with the various classes of animals. It is very evident from the data available that the experiment stations of the Corn Belt have been the leaders in this work. This is of course natural as swine raising is a major industry in this region and swine are very well adapted to experimental work with soy beans. There are perhaps three reasons for the wide use of hogs in soy bean feeding trials: first, because they require comparatively large amounts of concentrated feeds; second, because the results are quickly obtainable; and third, because the practice of hogging down soy beans in corn has become quite popular of late and has led to inquiries by farmers as to the value of the beans for hogs.

The work with beef cattle is a rather poor second in extent and value, while dairy cattle, horse, sheep and poultry experiments involving soy beans are practically non-existant. There has been enough information compiled from hog-feeding trials to enable one to draw fairly definite conclusions as to the value of soy beans in comparison to other protein concentrates. Such work as has been done with cattle and sheep gives some indication as to the value of the soy bean, but as a rule these cases, as well as those of horses and poultry, must be considered as somewnat analogous to the case of swine. Insofar as results of feeding trials are obtainable, the value of soy beans for hogs, sheep and cattle bears a rather definite relationship to the value of other protein concentrates for the same classes of animals. For example, we find that the comparative value of soy beans and tankage for hogs is very similar to the

comparative value of soy beans and cottonseed meal for cattle and for sheep. It is to be regretted that the scarcity of work done compels one to draw analogous conclusions, since these are of rather doubtful value. However, they must serve for the present as we have no other information upon which to base any definite conclusions.

Before taking up a review of the data on feeding trials, it will be well to learn something of the composition and relative digestibility of some of the more important nitrogenous concentrates. The following tables are taken from Henry and Morrison's "Feeds and Feeding", an acknowledged authority on the subject of American feeding stuffs.

Table I shows the average composition of various concentrated feeding stuffs.

Table II shows the average digestible nutrients in the same feeding stuffs.

Table I.

AVERAGE COMPOSITION OF VARIOUS AMERICAN FEEDING STUFFS.

	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N.F.E.	
Soy bean	9.9	5.3	36.5	4.3	26.5	17.5
Soy bean meal-fat extrac.	11.8	5.4	41.4	5.3	28.7	7.4
Velvet bean - seed	11.7	2.6	20.8	7.5	51.0	6.4
Cottonseed meal-choice	7.5	6.2	44.1	8.1	25.0	9.1
Cottonseed meal-prime	7.8	6.6	39.8	10.1	27.4	8.3
Cottonseed meal-good	7.9	6.4	37.6	11.5	28.4	8.2
Gluten feed	8.7	2.1	25.4	7.1	52.9	3.8
Gluten meal	9.1	1.1	35.5	2.1	47.5	4.7
Linseed meal-new process	9.6	5.6	36.9	8.7	36.3	2.9
Linseed meal-old process	9.1	5.4	33.9	8.4	35.7	7.5
Buttermilk	90.6	0.7	3.6	* *	5.0	0.1
Whole milk	86.4	0.7	3.5	* *	5.0	4.4
Skim milk	90.1	0.7	3.8	* *	5.2	0.2
Dried Blood	9.7	3.3	82.3	* *	3.8	0.9
Fish meal	10.8	29.2	48.4	* *	* *	11.6
Meat & Bone meal	6.0	36.8	39.8	2.1	4.1	11.2
Meat scrap-high grade	7.5	16.6	59.3	* *	5.0	11.6
Meat scrap-fair grade	6.7	25.5	52.0	* *	5.4	10.4
Tankage-60 per cent	7.4	10.5	63.1	3.6	2.5	12.9
Tankage-55 to 60 %	7.5	13.6	58.1	4.9	2.9	13.0
Tankage-45 to 55 %	7.5	19.7	51.7	3.0	4.2	14.0
Cow pea	11.6	3.4	23.6	4.1	55.8	1.5
Buckwheat bran	11.2	4.2	22.3	7.1	49.4	5.8
Wheat middlings-flour	10.7	3.7	17.8	4.7	58.1	5.0
Wheat middlings-shorts	10.5	4.4	17.4	6.0	56.8	4.9

Table II.

AVERAGE DIGESTIBLE NUTRIENTS IN VARIOUS

AMERICAN FEEDING STUFFS.

	Total Dry matter in 100 #.	Digestible nutrients in 100#				Nutritive Ratio
		Crude Protein	Carbohydrates	Fat	Total	
	#	#	#	#	#	1 :
Soy bean	90.1	30.7	22.8	14.4	85.9	1.8
Soy bean meal-fat extrac.	88.2	38.1	33.9	5.0	83.2	1.2
Velvet bean - seed	88.3	18.1	50.8	5.3	80.8	3.5
Cottonseed meal-choice	92.5	37.0	21.8	8.6	78.2	1.1
Cottonseed meal-prime	92.2	33.4	24.3	7.9	75.5	1.3
Cottonseed meal-good	92.1	31.6	25.6	7.8	74.8	1.4
Gluten feed	91.3	21.6	51.9	3.2	80.7	2.7
Gluten meal	90.9	30.2	43.9	4.4	84.0	1.8
Linseed meal-new process	90.4	31.7	37.9	2.8	75.9	1.4
Linseed meal-old process	90.9	30.2	32.6	6.7	77.9	1.6
Buttermilk	9.4	3.4	4.9	0.1	8.4	1.5
Whole milk	13.6	3.3	4.9	4.3	17.9	4.4
Skim milk	9.9	3.6	5.1	0.2	9.1	1.5
Dried Blood	90.3	69.1	* *	0.9	71.1	0.03
Fish meal	89.2	37.8	* *	11.6	63.9	0.7
Meat & Bone meal	94.0	37.0	* *	11.0	61.8	0.7
Meat scrap-high grade	92.5	55.1	* *	11.4	80.7	0.5
Meat scrap-fair grade	93.3	48.4	* *	10.2	71.4	0.5
Tankage-60 per cent	92.6	58.7	* *	12.6	87.0	0.5
Tankage-55 to 60 %	92.5	54.0	* *	12.7	82.6	0.5
Tankage-45 to 55 %	92.5	48.1	* *	13.7	78.9	0.6
Cow pea	88.4	19.4	54.5	1.1	76.4	2.9
Buckwheat bran	88.8	10.5	30.4	3.2	48.1	3.6
Wheat middlings-flour	89.3	15.7	52.8	4.3	78.2	4.0
Wheat middlings-shorts	89.5	13.4	46.2	4.3	69.3	4.2

In examining these tables, we notice the comparatively wide differences between "soy bean" and "soy bean meal- fat extracted". This is due to the extraction of the oil or fat, of which the soy bean has a considerable quantity. It is this excessive amount of oil which, in some experiments, has caused the feed to be unpalatable and lightly eaten. This, in turn, has resulted in less rapid and more costly gains causing the soy bean-fed lots to appear in an unfavorable light. It should be distinctly understood that soy bean meal is far superior to whole or ground soy beans as a protein concentrate simply because the excess of unpalatable oil has been removed.

We are more interested in Table II showing the average amounts of digestible nutrients in various nitrogenous concentrates because, no matter what the composition of a feed may be, the percentage of digestible nutrients it contains determines to a large extent its value as a feeding stuff. In this table we find that soy bean meal compares very favorably with other protein feeds of plant origin. In fact, it contains a higher percentage of digestible crude protein than does either of its principal competitors in the plant kingdom, cottonseed meal and linseed meal. There are three animal sources of protein which exceed soy bean meal in percentage content. They are dried blood, meat scrap and tankage. Of these three, however, only one, tankage of the highest quality, surpasses soy bean meal in amount of total digestible nutrients, an important consideration in selecting a protein concentrate. In comparing two feeds of approximately equal protein content and price, that feed having the larger amount of total digestible nutrients

offers better value for the money. In making a comparison of both tables with respect to the percentage of protein contained and the percentage of protein digested we find the following :

TABLE SHOWING THE PERCENTAGE OF PROTEIN DIGESTED.

	Protein contained in 100#.	Protein digested in 100#.	Percentage of protein digested.
	#	#	%
Skim milk	3.8	3.6	94.73
Tankage	63.1	58.7	93.02
Meat scrap	59.3	55.1	92.91
Soy bean meal	41.4	38.1	92.02
Linseed meal	33.9	30.2	89.08
Dried Blood	82.3	69.1	83.96
Cottonseed meal	44.1	37.0	83.90

From the above table we see that soy bean meal is excelled in percent of protein digested by skim milk, tankage and meat scrap. Milk protein is known to be the most easily digested and assimilated form of protein, consequently, we must expect that it will lead all other feeds. Tankage, having an animal protein, is only one per-cent more completely digested than soy bean meal. Meat scrap, also containing an animal protein, is less than nine-tenths of one per-cent closer to perfect digestibility. Soy bean meal leads all the feeds of plant origin with a percentage digestibility of 92.02, almost three per-cent more than linseed meal and over eight per-cent more than cottonseed meal. It is also over eight per-cent more completely digested than dried blood. As the cost of these commercial protein concentrates varies in proportion to the amount of protein they contain, it is to the feeder's advantage to calculate carefully the ratio between the per-cent of protein digested and the

cost of any feed under consideration. A feed of lower protein content but of higher protein digestibility may easily furnish a considerably larger amount of protein per unit of cost than a feed of greater protein content but lesser digestibility.

Work done in nutrition laboratories throws some light upon the digestibility and value of soy bean protein. Osborne and Mendel[1] in rat experiments in which ground soy beans and a commercial soy bean meal served as the sole source of protein in the ration found that the raw soy beans were unpalatable. However, when they were mixed with distilled water to a mush, cooked three hours on a steam bath and dried at 80° to 90° F., they were eaten with relish and promoted growth at the normal rate. They also found that the soy bean meal treated similarly produced like results. In another trial[2] the same investigators found that soy bean flour formed a favorable supplement to corn gluten in rat feeding experiments.

One fact which has been brought out both in laboratory work and in feeding trials is that soy beans donot satisfactorily supplement the lack of calcium in corn. Daniels and Nickols[3] in determining the nutritive value of the soy bean in rat experiments find that the water-cooked soy bean alone is insufficient to support life and growth, but if supplemented by inorganic substances, such as calcium, chlorine or sodium, makes a good ration. They find that it contains a high percentage of energy yielding material in the form of fat and carbohydrate, a high

1. Jour. Biol. Chem. v.32-pp.369-387.
2. Jour. Biol. Chem. v.29-pp.29.
3. Jour. Biol. Chem. v.32-pp.91-102.

percentage of physiologically good protein, and a fairly liberal supply of the fat-soluble food accessory as well as of the water-soluble growth determinant.

Forbes of the Ohio Station[1] in a study of the digestion and retention of organic and inorganic constituents of rations consisting of corn alone or of corn with various supplements, finds that soy beans as a supplement in one group fail to completely make up for the lack of calcium in corn.

However, this lack of a proper calcium supplement in soy beans when fed with corn to hogs is not as serious as might at first be supposed because it is easily remedied by providing a suitable mineral mixture in a self-feeder. Many authorities advise the use of a mineral supplement at all times regardless of what protein supplement is used with the corn. A good mineral supplement is cheap and it insures against any lack of minerals in the feeds.

1. Ohio Bulletin #271 - pp.225-261.

II. SOY BEANS FOR HOGS.

It has seemed advisable to begin the study of soy bean feeding trials for animals with those concerning hogs because of their greater number and variety. There are several ways in which soy beans in some form may be fed to animals. They may be fed whole as cull beans; they are often fed ground; the soy bean meal is becoming more and more important as a feed; they are often hogged down with corn; they are used to some extent as a pasture crop; some cattle feeders use a corn-soy bean silage; and finally, soy bean hay is an excellent roughage, comparing very favorably with alfalfa and clover hays.

The practice of feeding whole or ground soy beans to hogs is apparently becoming less common as the greater efficiency of the soy bean meal becomes better known. Of course, in hogging down soy beans and corn the beans must be fed whole, but as one of the primary advantages of hogging down is in the saving of labor, it would not be in accord with the labor-saving policy to harvest and grind the beans before feeding them to the hogs. As has been stated before, neither the whole nor the ground beans are as efficient producers of pork as is soy bean meal because they contain a large amount of unpalatable oil.

There have been numerous experiments dealing with the relative value of soy bean meal and ground soy beans. These experiments are unanimous in demonstrating the superiority of the meal. An experiment conducted at the Ohio Station[1] shows this clearly. The hogs were fed seven weeks in dry lot on a corn-soy bean meal and a corn-ground soy bean ration. The results are as

1. Ohio Monthly Bulletin. Vol.5- No.4.

follows:-

SOY BEAN MEAL vs GROUND SOY BEANS.

	Corn-8 parts S.B.M.-1 part	Corn-24 parts Grd.S.B.-5 parts
Initial weight	103 #	103 #
Ave. daily gain	1.67 #	1.40 #
Feed per 100# gain		
Corn	315 #	313 #
Supplement	39 #	65 #
Total	354 #	378 #

In another experiment at the Ohio Station[1], hogs fed from the self-feeder for seven weeks in dry lot gave similar results:-

SOY BEAN MEAL vs GROUND SOY BEANS.

	Corn-16.9 parts S.B.M.- 1 part	Corn-25.8 parts Grd.S.B.- 1 part
Initial weight	54 #	54 #
Ave. daily gain	1.33 #	1.17 #
Feed per 100# gain		
Corn	387 #	426 #
Supplement	22 #	16 #
Total	409 #	442 #

In still another experiment at the Ohio Station[1], in which the hogs were fed soy bean meal and ground soy beans while on rape pasture for seventeen weeks, the following results were secured:-

SOY BEAN MEAL vs GROUND SOY BEANS.

	Corn-12 parts S.B.M.-1 part	Corn-8 parts Grd.S.B.-1 part
Initial weight	67 #	67 #
Ave. daily gain	1.60 #	1.38 #
Concentrates per 100# gain		
Corn	356 #	369 #
Supplement	29 #	46 #
Total	385 #	415 #

Other experiments conducted at various stations bear out these results quite well and it would be useless to enumerate

1. Ohio Monthly Bulletin. Vol.5- No.4.

them all here as it would merely waste space and time. The experiments noted above are typical and they serve to show that ground and whole soy beans are not as well suited to produce pork as efficiently and as economically as is soy bean meal when fed as a supplement to corn.

It is important that we keep clearly in mind the difference between soy bean meal and ground soy beans because in the feeding trials mentioned later, when other protein concentrates are compared with ground soy beans, we may safely assume that had soy bean meal been used instead, the results would have been more favorable to the soy bean. There is also considerable variation in the results secured with soy bean meal, due to the variation in the composition of the meal. As yet the manufacture of this feed has not been standardized to such a degree as that of tankage or linseed meal, so that different lots of the soy bean meal may vary considerably in percentage content of protein and oil. Consequently, a lot somewhat low in protein will not compare as favorably with tankage as will a lot having a higher percentage of protein. In view of this varying composition, it is always best to purchase soy bean meal on a guaranteed analysis basis so that one may know about what to expect when the meal is fed to livestock.

When we study hog feeding trials, particularly those of the Corn Belt, we find that four protein supplements stand out above all others. These four have come to be generally adopted because of their known value as hog feeds. In order of their value as supplements to corn for growing and fattening hogs

they are, skim milk, tankage, linseed oil meal and wheat middlings. It is generally conceded that these feeds are the best supplements to corn for fattening hogs, so that if we compare soy beans with these four feeds we shall be able to get a very definite idea as to the value of the soy bean.

Skim milk is often spoken of as the ideal supplement to corn because it is very palatable, rich in protein (on a dry basis), very easily and completely digested, and produces more rapid gains than other supplements. If it can be obtained in sufficient quantity at a reasonable price, it does form an ideal supplement. However, on Corn Belt farms generally, these last two points, quantity and cost, are an effective barrier to its universal adoption. There is also one other minor disadvantage in using skim milk which is really of no great importance providing that proper care is taken in producing the milk. It has been shown that hogs fed skim milk are more likely to develope tuberculosis than those fed tankage, linseed meal, etc. The danger from this disease is very slight if healthy cows are used and if the milk is pasteurized before being fed to hogs.

As a result of the undoubted superiority of skim milk as a supplement to corn for hogs, very little work has been done involving comparisons of milk with other protein feeds. An experiment performed at the Purdue Station[1] shows very clearly the superiority of skim milk to soy bean meal. The hogs were fed for sixty days in dry lot on rations of corn meal-skim milk and corn meal-soy bean meal.

1. Purdue Bulletin No. 137.

SKIM MILK vs SOY BEAN MEAL

	Corn meal-1 part Skim milk-1.5 parts	Corn meal-8 parts S.B.M.- 1 part
Initial weight	105 #	105 #
Ave. daily gain	1.76 #	0.90 #
Feed per 100# gain		
Corn meal	267 #	363 #
Supplement	400 #	47 #

While in other experiments the difference is not so marked, as a general rule skim milk has been proved to be a better producer of pork than soy bean meal. However, it has also proved better than tankage or linseed meal so that soy bean meal is in no way discredited by its failure to equal the value of skim milk. Indeed, in some experiments involving comparisons of skim milk, tankage, soy bean meal, linseed meal, wheat middlings, etc., soy bean meal has more closely approached skim milk in value as a hog feed than any other protein supplement. One experiment in particular gave the following results:-[1]

COMPARISON OF PROTEIN SUPPLEMENTS.

Ration	Feed per 100# gain	Dry matter per 100# gain	Cost per 100# gain
	#	#	$
Corn meal and skim milk	297 meal 445 milk	297 #	3.56
Corn meal and soy bean meal	367 #	319 #	3.57
Corn meal and linseed meal	375 #	325 #	3.63
Corn meal and tankage	383 #	331 #	3.71
Corn meal and middlings	361 #	319 #	3.88

These feeding trials serve to show that skim milk is a more efficient producer of pork than soy bean meal, and numerous trials might be cited to prove that it is also superior to any other nitrogenous supplement to corn.

Granting, therefore, that milk is preeminent, let us next examine the relative values of soy bean meal and linseed meal.

1. Indiana Bulletin No. 137.

There has been considerable work done with these two feeds as a feed for hogs because they are rather similar in their chemical composition and the natural question that arises is, "Which is better for fattening and growing hogs?" To give the results of all these experiments would require an excessive amount of space, so we shall confine ourselves to the average results. The complete records can easily be found by reading the bulletins noted below[1]. We find upon averaging the results of trials with corn and soy bean meal as compared to corn and linseed meal that the former ration has produced more rapid gains on less feed per unit of gain. In only one instance did the linseed meal-fed hogs have a better average daily gain and in this instance it was only .08 of a pound greater. The initial weights of the hogs varied from 67 pounds to 118 pounds so that both growing and fattening classes are represented. The average results are as follows:-

SOY BEAN MEAL vs LINSEED MEAL.

	Corn-6.56 parts S.B.M.- 1 part	Corn-6.19 parts L.O.M.- 1 part
Initial weight	99.5 #	99.5 #
Ave. daily gain	1.42 #	1.37 #
Feed per 100# gain	371 #	396.5 #

From the above we may readily see that soy bean meal is a more rapid and more economical producer of pork than is linseed meal. In the experiments used in averaging, the soy bean meal hogs' average daily gain ranged from .01 pounds to .10 pounds greater than that of the linseed meal hogs. The average as shown is .05 pounds greater daily gain. The feed per 100 pounds gain in the

1. Purdue Bulletin No. 126.
   Purdue Bulletin No. 137.
   Ohio Monthly Bulletin -Vol.5- No.4
   Ohio Bulletin No. 316.
   Missouri Bulletin No.81.

soy bean meal lots ranged from 7 pounds to 55 pounds less than in the linseed meal lots with an average of 25.5 pounds less feed per 100 pounds of gain.

Inasmuch as available information is practically unanimous in showing that hogs fed soy bean meal as a supplement to corn in dry lot make faster daily gains and make these gains on less feed per 100 pounds of gain, we are warranted in concluding that under average Corn Belt conditions, the feeder will profit more by feeding soy bean meal than by feeding linseed meal. When we consider that soy bean meal and linseed meal ordinarily sell for about the same price per ton, we can see that the use of soy bean meal is more economical. Then, when we consider that the soy bean can be produced on most Corn Belt farms and that it has a beneficial effect on the soil, it is easy to understand why the soy bean is superior in all respects to linseed meal.

The results of experimental work with soy bean meal and tankage as supplements in fattening hogs are of the see-saw variety, the tankage giving better results at times and at other times not being as good as the soy bean meal. The reason for this probably lies in the fact that the soy bean meal varies considerably in composition. At such times as it contained a smaller percentage of oil and a larger percentage of protein it proved to be more palatable, more was eaten and consequently, better results were obtained. The results of all these tankage-soy bean meal trials are very close, so close in fact that a few dollars difference in the cost of a ton of tankage or a ton of soy bean meal would make a decided difference in which was the most economical feed. The results of two feeding trials will be cited, the first,

one in which tankage showed the greatest superiority and the second, one in which soy bean meal proved most superior.

In the first experiment[1] the hogs were fed for 56 days in dry lot with 10 hogs in a lot. In the second experiment[2] the hogs were fed for 12 weeks in dry lot with 10 hogs in a lot. The results of these trials are as follows:-

SOY BEAN MEAL vs TANKAGE.

	Corn meal-10 parts S.B.M.- 1 part	Corn meal-14 parts Tankage- 1 part
Initial weight	143 #	147 #
Ave. daily gain	1.50 #	1.66 #
Feed per 100# gain	449 #	406 #
* * * * * * * * * * * * * * * * * * * *		
	Corn meal-2 parts S.B.M.- 1 part	Corn meal-5 parts Tankage- 1 part
Initial weight	55 #	55 #
Ave. daily gain	1.19 #	1.03 #
Feed per 100# gain	310 #	362 #

These two trials represent the extreme differences between the two feeds. The majority of the experiments showed that there was very little difference between the relative feeding values of the two concentrates. As in the case of linseed meal and soy bean meal, we will average the results obtained in all the trials.[3]

SOY BEAN MEAL vs TANKAGE.

	Corn-7.9 parts S.B.M.-1 part	Corn-11.9 parts Tankage-1 part
Initial weight	104.5 #	105.2 #
Ave. daily gain	1.51 #	1.56 #
Feed per 100# gain	389.5 #	385.8 #

This is indeed a very creditable showing for soy bean meal in

1. Kentucky Bul. No.175.
2. Purdue Bul. No.108.
3. Ohio Monthly Bulletin -Vol.5- No.4.
   Ohio Bulletin No.316.
   Idaho Bulletin No.74.
   Missouri Bulletin No.81.
   Purdue Bulletin No.108.
   Kentucky Circular No.20.
   Purdue Bulletin No.137.
   Kentucky Bulletin No.175.

comparison with a feed long recognized as an excellent supplement to corn in growing and fattening hogs. Furthermore, when we consider that tankage is uniformly higher in price than soy bean meal and that the soy bean can be produced on the farm where it is to be fed, there can be little doubt that the farmer who replaces tankage with soy bean meal should find his cost of producing hogs materially reduced. Another point to be kept in mind in reviewing these soy bean-tankage comparisons is that in many instances ground soy beans were labelled "soy bean meal" when in truth they were not true meal with the excess oil removed. Had real soy bean meal been used in all the trials, it is probable that the two feeds would have been still closer in value.

In comparing soy bean meal with the remaining important protein supplement, wheat middlings, we find once more that the meal has been shown to be of greater value for hogs. Trials comparing these two feeds are not as numerous as those involving tankage and linseed meal, probably because of the lesser importance of middlings as a hog feed in the Corn Belt.

An average of the information available shows clearly the superiority of the soy bean meal:-[1]

SOY BEANS vs WHEAT MIDDLINGS.

	Corn-5.4 parts S.B.M.-1 part	Corn-2 parts Middlings-1 part
Initial weight	95.3 #	95.6 #
Ave. daily gain	1.48 #	1.36 #
Feed per 100# gain	349.8 #	377.5 #

In only one instance did the middlings-fed hogs gain more rapidly

1. Wisconsin Station Annual Report 1905.
Wisconsin Station Annual Report 1906.
Purdue Bulletin No. 108.
Purdue Bulletin No. 137.
Missouri Bulletin No. 81.

and in this case the feed required per 100 pounds gain was practically the same for both lots. From a consideration of the data on soy beans and middlings, it appears that we are again warranted in concluding that soy beans are superior.

To summarize the results of feeding trials involving soy beans and other protein concentrates we find that according to all data available on the subject, skim milk is the most desirable as a feed providing that it can be obtained in sufficient quantity and at a satisfactory price. Next, we find that tankage and soy bean meal are practically equal in value, and last, that soy bean meal is superior to linseed meal and wheat middlings. When we consider the other advantages accruing to the farmer who produces the soy beans to feed his hogs, the superiority of the legume is very evident.

The principal advantages are in the saving of cost effected by the home-production of a protein supplement, the enriching of the soil upon which the soy beans are grown, and the adaptability of the crop to various uses such as hay, forage, cover crops, soiling crops, etc. The other plant sources of protein concentrates offer no such advantages as these.

Soy bean meal is, in addition, a by-product of the manufacture of soy bean oil, so that besides getting a protein concentrate to use as a stock feed the farmer has at his command a commodity for which there is a steady demand.*

However, at the present time it must be admitted that both tankage and linseed meal are far more widely used than soy

* A plan will be suggested later, whereby the farmer will be able to obtain his soy bean meal at a very low cost from the soy beans produced on his own land.

bean meal. This is because the value of the soy bean product is less known; because it is produced in much smaller quantities and is thus harder to secure; and because it is not so uniform in composition, thus making it less reliable as a feed. It is not too much to assume that these disadvantages will be overcome and that before long, soy bean meal will, to a large degree at least, replace the other protein supplements in hog feeding.

One of the principal uses of soy beans at the present time is in hogging them down. They are usually planted with the corn but are sometimes used as pasture and supplemented with corn in a self-feeder. When planted with the corn, the yield of corn in bushels per acre is usually reduced by about the same number of bushels of beans produced, but at the same time the feeding value of an acre of corn and soy beans is considerably in excess of the feeding value of an acre of corn alone. The advantages of hogging down corn and soy beans may be stated as follows:-

1. It makes a well balanced ration for the hogs, especially if they are furnished a mineral mixture to make up for the lack of ash in the soy beans and corn.

2. It provides a home-grown protein supplement to corn.

3. The soy bean roots and what remains of the leaves and stems add greatly to the fertility of the soil.

4. It will produce considerably more pork to the acre than will corn alone.

5. It is an economical method of producing pork because of the saving in labor. In fact in economy of gains, the hogging down of corn and soy beans together is superior to the practice of hogging down corn supplemented by tankage in a self-feeder, although the latter method will likely produce more rapid gains.

The disadvantages of hogging down are considerably over-balanced by the advantages. The disadvantages may be listed

as follows:-

1. The whole soy beans are unpalatable to hogs and will not produce such good gains as will soy bean meal.

2. There is some extra expense and labor incurred in providing fencing, etc.

3. There is danger of puddling the field in wet weather.

One other feature that may be regarded as an advantage of hogging down soy beans supplemented by corn is in the manurial value of such a practice. In 1000 pounds of soy beans there are 58.4 pounds of nitrogen, 24.7 pounds of potash and 13.7 pounds of phosphoric acid. [1] Experiments have shown that about 85 percent of the fertilizing materials fed a hog is passed out in the solid and liquid manure. The Kentucky Station did some work along this line and their conclusions are interesting.[2] They hogged down soy beans with a 20 bushel yield and supplemented them with 1597 pounds of corn meal. Their estimate as to the manurial value of the experiment is as follows:-

VALUE OF MANURE.

In manure	Value per pound	Total value per lot
Nitrogen	$0.18	$10.72
Phosphoric acid	0.05	.70
Potash	0.06	1.51
Manurial value of corn meal fed	* *	4.75
Total value of manure		$17.68

This value is in addition to the fertility conserved by the roots of the plants, which amounts to quite a good deal as they store nitrogen, the most expensive fertilizing material. While the figures in the above estimate will vary according to the prices of the different constituents, the principal remains the same.

1. Henry & Morrison, "Feeds and Feeding,"
2. Kentucky Bulletin No.201

Soy beans are also used for pasture for hogs without considering the production of the beans themselves. Experiments conducted at the Ohio Station[1] seem to indicate that soy bean pasture is not quite as valuable as second growth red clover or rape but is markedly superior to sweet clover. Hogs fed a corn ration for 76 days while on rape, red clover and soy bean pasture gave the following results:-

SOY BEANS vs RAPE AND RED CLOVER AS PASTURE.

	Rape	Red Clover	Soy Bean
Initial weight	69 #	72 #	70 #
Ave. daily gain	1.45 #	1.70 #	1.54 #
Corn per 100# gain	384 #	376 #	394 #

The clover pasture is superior in this trial as it produced the most rapid gains and required less corn per unit of gain. Altho the lot on rape pasture required less corn per 100 pounds gain, the hogs on soy bean pasture gained more rapidly.

In another trial at the Ohio Station[2] in which the hogs were fed corn and corn-tankage rations for 10 weeks while on clover and soy bean pastures, the following was observed:-

SOY BEANS vs SWEET CLOVER AS PASTURE.

	Clover pasture		Soy Bean pasture	
	Corn	Corn & Tank.	Corn	Corn & Tank.
Initial weight	55 #	55 #	55 #	55 #
Ave. daily gain	.99 #	1.04 #	1.24 #	1.23 #
Concentrates per 100# gain				
Corn	362 #	327 #	289 #	277 #
Tankage	* *	16 #	* *	14 #
Total	362 #	343 #	289 #	291 #

This experiment shows forcibly the superiority of soy bean pasture to sweet clover pasture. Furthermore, it shows that while tankage proved beneficial to hogs on sweet clover, it was not

1. Ohio Bulletin No.242.
2. Ohio Bulletin No.343.

needed by the soy bean lots. The Ohio Station comments as follows in regard to the soy bean pasture:- "While the soy bean plant is palatable, makes fairly efficient forage and furnishes green food during the late summer when pastures are likely to be short, as a pasture crop it is subject to the criticism that it doesnot produce new growth after being pastured and so gives forage for only a comparatively short time."

Although the foregoing information is rather meagre in extent, it may be accepted as an indication of the relative value of the various crops as pasture for hogs. Red clover seems to be the most satisfactory. Rape and soy beans may be regarded as approximately equal in value, although when the soil-enriching properties of the legume are considered we may safely assume that the latter is to be preferred, and finally, soy beans seem to be considerably superior to sweet clover.

As very little use is made of hay for feeding hogs, information on the value of soy bean hay is noticeably lacking. What little is available, especially pertaining to its use for wintering brood sows, seems to indicate that soy bean hay compares very favorably with alfalfa and clover hays for this purpose.

There has been some question as to the quality of pork produced by soy bean-fed hogs. There has been a belief that soy beans have an effect somewhat similar to peanuts in producing soft pork. While there has not been very much work done on this problem, all sources available state that such a belief is unsupported by fact. The Missouri Station states[1], "The linseed oil meal hogs were characterized by conspicuous thickness, firm-

1. Missouri Bulletin No.81.

ness and especially evenness, of the covering of fat.----The soy bean hogs were slightly less firm than the linseed oil meal hogs, but not objectionably so."

It is well known that wheat middlings are very valuable for producing high quality pork. Consequently, the report of the Wisconsin Station[1] is to be expected. They say, "---in firmness, fine grain and texture of flesh, and in even distribution of fat and lean, the middlings and corn meal ration was superior to that of soy beans and corn meal." In an experiment at the Ohio Station[2], the various lots ranked in hardness of fat as follows:- Corn-skim milk; corn-middlings; corn alone;corn-linseed meal; corn-tankage; and corn-soy beans. This last would indicate that soy beans do have a tendency to produce soft pork but the large bulk of evidence seems to show that the fat of soy bean-fed hogs is not as objectionably soft as has been commonly believed.

1. Wisconsin Annual Report 1906.
2. Ohio Bulletin No.263.

III. SOY BEANS FOR BEEF CATTLE.

Experimental work involving the use of soy beans for beef cattle, although not very extensive, gives us some idea as to what may be expected from the crop. Those beef cattle feeding experiments conducted in the South have been on a somewhat different basis from the ordinary run of Corn Belt feeding trials, the southern idea being to ascertain how much beef could be produced from an acre of land, while the Corn Belt stations have remained true to the comparative method of feeding trials. The former method seems to be somewhat preferable as it gives a better answer to the question, "What is the maximum amount of beef that an acre will produce?" In the long run, this is what the farmer is most interested in. He wants to know, not so much how soy beans compare with some other feed, but the maximum amount of beef he can market from his acres under proper conditions.

In trying to answer this question, the Tennessee Experiment Station has brought to light some interesting and valuable information in regard to the value of the soy bean as a feed for beef cattle. One of their earlier experiments[1] was conducted as follows:-

Three lots of four steers each were fed in covered pens from one acre each of corn, soy beans and cow peas so that each lot received only the product of one acre in addition to a basal ration of 20 pounds of corn silage per head per day. The crops were planted, cared for and harvested just as ordinary farm crops are handled. The corn was harvested and cured in the field, the ears being made into corn and cob meal and the stalks cut in a

[1] Tennessee Bulletin No.79.

silage cutter. The soy beans and cow peas were also cured in the field and the beans and peas threshed out and ground into a coarse meal. The roughages and concentrates were weighed and thoroughly mixed before feeding. The results of the first year's trial were so unlooked for that a second trial was made and very similar results secured. The rations fed in both years were as follows:-

Soy bean lots
First 30 days- 3# soy bean meal
11# soy bean straw
20# corn silage
Second 50 days, 4# soy bean meal
11# soy bean straw
20# corn silage

Cow pea lots
First 30 days- 3# cow pea meal
11# cow pea straw
20# corn silage
Second 24 days- 4# cow pea meal
11# cow pea straw
20# corn silage

Corn lots
First 30 days- 8# corn and cob meal
8# corn stover
20# corn silage
Second 24 days-12# corn and cob meal
7# corn stover
20# corn silage

During the second year's trial similar amounts of concentrates were fed but the roughage was reduced slightly in all cases to avoid all possible waste.

The results of these two year's trials were as follows:-

COMPARISON OF SOY BEAN, COW PEA AND CORN ACRES.

1906	Concentrates eaten	Roughage eaten	Silage eaten	Ave. daily gain	Concentrates per lb. gain
Lot I. Soy beans	1133#	3585#	6814#	1.27#	2.78#
Lot 2. Cow peas	751	2404	4240	1.21	2.87
Lot 3. Corn	2450	1912	4320	0.59	19.10
1907					
LotI. Soy beans	1184#	3280#	6640#	1.68#	2.19#
Lot2. Cow peas	751	2404	4400	1.51	2.29
Lot3. Corn	2455	1632	4400	0.94	12.06

This experiment shows clearly that the soy beans and cow peas balanced the ration, soy beans a little better than cow peas. The soy beans also improved the palatability of the ration judging from the much larger amount of roughage consumed. Furthermore, the acre of soy beans supported the four steers for 80 days while the corn and cow pea acres lasted only 54 days in both trials. In ability to produce pounds of beef per acre, soy beans are undoubtedly superior to either corn or cow peas. Incidentally, it cost less to produce the acre of soy beans than it did either of the others.

In 1908, the Tennessee Station began a series of experiments the primary object of which "was to determine the amounts of beef that an acre of land would produce if the crops grown upon it were fed to livestock."[1] Eventually seven acres were used to produce feed for steer feeding. Barley was planted on the land in the fall and harvested the following spring in time to plant soy beans, cow peas and corn. The barley grain was fed with the other crop produced on the same acre. In this way, greater gains were secured on stock fed from these acres.

1. Tennessee Bulletin No.114.

The crops grown were as follows:-

Acre 1. Barley and soy beans.

Acre 2. Barley and cow peas.

Acre 3. Barley and corn.

Acre 4. Barley and soy beans, with soy beans harvested as hay.

Acre 5. Wheat and soy beans.

Acre 6. Oats and soy beans, with soy beans harvested as hay.

Acre 7. Alfalfa hay.

In all feeding work a basal ration of 20 pounds corn silage per head per day was fed. The grains were ground and the hays and stovers cut up.

GAINS PER ACRE WITH VARIOUS CROPS.

	1908	1909	1910	1911	1912	1913	1914	Aver.
Acre 1.	673#	632#	609#	420#	364#	367#	494#	508 #
Acre 2.	529	561	441	305	366	528	370	451
Acre 3.	602	476	708	350	169	355	378	434
Acre 4.	* *	517	461	393	241	518	372	435
Acre 5.	* *	* *	* *	354	347	493	412	402
Acre 6.	* *	* *	* *	570	400	485	367	456
Acre 7.	* *	* *	758	302	431	581	502	515

When the returns over a term of years are considered, alfalfa hay and the combination of soy beans and barley stand out as the best producers of beef on an acre basis. In gross returns per acre the combination of soy beans and barley heads the list with soy bean hay and oats second. This was figured with beef valued at 6 cents, silage at 3 dollars per ton and a 1 dollar margin on 1000 pound steers for 60 to 90 days. The gross returns

from the seven lots were as follows:-

Acre 1.	$61.23	Acre 2.	$58.94
Acre 3.	$56.92	Acre 4.	$57.07
Acre 5 .	$55.99	Acre 6.	$59.23
Acre 7.	$58.91		

In considering the comparative value of soy beans and cottonseed meal as protein concentrates for beef cattle, we find that very little work has been done. The Purdue Station conducted two trials in the winter feeding of steers in which these two feeds were compared. In the first trial[1], 20 steers in two equal lots were fed shelled corn, corn silage and oat straw together with either soy bean meal or cottonseed meal for 180 days. The results of this trial were as follows:-

SOY BEANS vs COTTONSEED MEAL.

	Shelled corn Corn silage Oat straw Soy bean meal	Shelled corn Corn silage Oat straw Cottonseed meal
Initial weight	8302 #	8298 #
Final weight	12277 #	12632 #
Ave. daily gain	2.21 #	2.41 #
Feed per 100# gain		
Shelled corn	576 #	570 #
Soy bean meal	116 #	
Cottonseed meal		107 #
Corn silage	1085 #	1094 #
Oat straw	32 #	27 #
Total	1809 #	1798 #

This experiment was repeated the following year[2] using similar sized lots and similar rations. The cattle in the second trial were fed 175 days, from November 20 to May 14 the next year. The results of this second experiment were as follows:-

1. Purdue Bulletin No.167.
2. Purdue Bulletin No.178.

SOY BEANS vs COTTONSEED MEAL.

	Shelled corn Corn silage Oat straw Soy bean meal	Shelled corn Corn silage Oat straw Cottonseed meal
Initial weight	9785 #	8876 #
Final weight	13558 #	12882 #
Ave. daily gain	2.16 #	2.54 #
Feed per 100# gain		
Shelled corn	616 #	554 #
Soy bean meal	135 #	
Cottonseed meal		121#
Corn silage	937 #	1030 #
Oat straw	73 #	45 #
Total	1761 #	1750 #

The results of these two trials are very favorable indeed to soy bean meal, especially when we consider that the "meal" was really ground soy beans, as the author states that the beans were simply ground in a mill owned by the station. As has been pointed out previously, ground soy beans are considerably inferior to soy bean meal as a feed for hogs. It is fair to assume that the same is true for cattle because the bulletin states in the first experiment that "After about three months on feed the cattle of Lot 1 ceased to have the keen, eager appetites desirable in fattening stock. It was necessary during the last three months to exercise constant care in preventing them from going off feed. The cattle fed soy beans were loose at all times". These two circumctances seem to indicate that there was a considerable excess of unpalatable oil in the beans. This oil is very distasteful to hogs and doubtless has a similar affect on cattle, although it was less pronounced in this case. However, the second trial was very successful in showing the undesirable affect of the soy bean oil. The soy bean lot went off feed badly in the fourth month, dropping from an average daily gain of 2.43 pounds in the third month to

0.82 pounds in the fourth.

Notwithstanding the fact that ground soy beans were used in these trials rather than soy bean meal, they made an excellent showing compared to the standard protein supplement for beef cattle. The author of the bulletin states, "Considering the excellent results secured during the first three months of the feeding period (in the second trial) and the smaller quantity of feed eaten during the last three months by the cattle receiving ground soy beans, indications are that the nutritive value of ground soy beans is as high as that of cottonseed meal provided some means is found for maintaining the appetites of the cattle for soy beans and preventing scouring." Had real soy bean meal been fed, the cattle would in all probability have maintained their appetites and there would have been no scouring.

In another experiment conducted at the Purdue Station[1] in which seven lots of cattle of ten each were fed 150 days beginning December 16, the value of the soy beans was again forcibly brought out. The rations fed were as follows:-

Lot 1. Shelled corn, ground soy beans, corn silage, oat straw.

Lot 2. Shelled corn, cottonseed meal, clover hay.

Lot 3. Shelled corn, cottonseed meal, alfalfa hay.

Lot 4. Shelled corn, cottonseed meal, corn silage, clover hay.

Lot 5. Shelled corn, cottonseed meal, cane molasses, clover hay, corn silage.

Lot 6. Shelled corn, proprietary molasses feed, clover hay, corn silage.

Lot 7. Shelled corn, cottonseed meal, alfalfa hay, corn silage

1. Purdue Bulletin No. 183.

The results of this trial were as follows:-

SOY BEANS vs COTTONSEED MEAL.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Initial weight(lbs)	11686	11652	11626	11657	11712	11655	11695
Final weight(lbs)	15637	15660	15417	15060	15628	14760	15635
Ave.daily gain(lbs)	2.63	2.67	2.53	2.27	2.61	2.07	2.63
Feed per 100# gain							
Shelled corn	542	661	699	598	416	567	517
Ground soy beans	128						
Cottonseed meal		124	130	144	128		127
Cane Molasses					109		
Mixed molasses feed						266	
Clover hay		501		211	182	231	
Alfalfa hay			522			-	113
Oat straw	35						
Corn silage	1037			1100	1117	1220	1080
Total	1742	1286	1351	2053	1952	2284	1835

The soy bean lot stood second in rapidity of gain, putting on only 0.04 pounds less per day than Lot 2; third in total feed consumed, Lots 2 and 3 eating less; third in feed per 100 pounds gain; second in total gain; and first in cost of gain per 100 pounds, costing 71 cents less per 100 pounds than the next nearest lot. Although there is no exact comparison possible between the soy beans and the cottonseed meal because no two lots were fed exactly alike, Lots 4 and 7 are most nearly comparable, differing from Lot 1 only in the use of clover hay and alfalfa hay instead of oat straw and in the use of cottonseed meal instead of ground soy beans.

Lots 1 and 7 were very nearly alike in total gain and in feed per 100 pounds gain, while they both gained at the same rate, 2.63 pounds per head per day. Lot 1 made a greater total gain and a more rapid gain than Lot 4 and did it on considerably less feed per 100 pounds gain. In cost of gains at prices then prevailing (1914) Lot 1 had a considerable lead over both Lots 4 and

7, due of course to the fact that they used oat straw as a dry roughage rather than clover or alfalfa hay. When the pork produced was considered, Lot 1 was the only one of the seven to show a net profit. The author comments as follows:- "This trial corroborates previous experiments in which it was shown that if the appetites of the stock can be maintained-----ground soy beans make an excellent feed for cattle."

In an experiment extending over a four year period at the Purdue Station[1], two groups of steers of two lots each were fed to compare corn silage with corn and soy bean silage. One group was fed cottonseed meal and the other was not. The rations of the lots were as follows:-

Lot 1. Shelled corn, cottonseed meal, clover hay, corn silage.

Lot 2. Shelled corn, cottonseed meal, clover hay, corn and soy bean silage.

Lot 3. Shelled corn, clover hay, corn silage.

Lot 4. Shelled corn, clover hay, corn and soy bean silage.

There were 10 steers in each lot each year and the rations were the same in every trial. The feeding periods began about December 10 each year and lasted for from 120 to 150 days. The results of the four years trials, averaged, are as follows:-

CORN AND SOY BEAN SILAGE vs CORN SILAGE.

	Lot 1	Lot 2	Lot 3	Lot 4
Initial weight(lbs)	9474	9469	9249	9459
Total gain(lbs)	3184	3280	2914	2951
Ave. daily gain(lbs)	2.37	2.43	2.15	2.18
Feed per 100# gain				
Shelled corn	507	491	603	587
Cottonseed meal	114	111		
Corn silage	1395		1585	
Corn and SB silage		1348		1501
Clover hay	149	144	169	165
Total	2165	2094	2357	2253

1. Next page.

Comparing the lots with similar rations we find that in both instances those fed the corn and soy bean silage gained slightly more rapidly and with slightly less feed per 100 pounds gain. The differences in rate of gain and amount of feed per unit of gain between the lots fed cottonseed meal and those not fed it indicate that the protein contained in the soy beans was insufficient in amount to properly balance the ration. However, the soy beans made up a little of the protein lack as evidenced by the fact that Lot 4 required 7.5 percent more feed to produce 100 pounds of gain than Lot 2, while Lot 3 required 8.8 percent more than Lot 1.

On the whole, however, there is very little difference in feeding value between corn silage and corn-soy bean silage, particularly for winter fattening steers. It is probable that corn-soy bean silage would be of more value in wintering breeding cows than would corn silage as it would make possible the reduction in amount of the concentrated protein feed and thus reduce expenses, while still maintaining the condition of the cows.

The work here recorded, while not as extensive as one would wish, serves very well as an indication of the value of soy beans as a protein supplement in feeding beef cattle. The fact that ground soy beans gave such excellent results when compared with cottonseed meal leads one to believe that soy bean meal will probably prove superior to cottonseed meal. It is to be hoped that experiments dealing with this problem will be undertaken before long.

1. (Pg.58) Purdue Bulletin No.220,240,249,255.

IV. SOY BEANS FOR OTHER CLASSES OF LIVESTOCK.

Unfortunately there is very little information available regarding the value of the soy bean or its products for dairy cattle, sheep, poultry or horses. A few things have been learned but on the whole, nothing very definite may be concluded from a study of the data. As there is more information about soy beans for dairy cattle, we will begin with a study of it.

DAIRY CATTLE.

The use of soy beans as silage assumes more importance with dairy cattle than with any other class of stock, but at the same time there has probably been more work done with soy bean meal than with soy bean silage. However, a comparison of the chemical compositions of the various silages and forages will be helpful. The accompanying table gives this comparison.[1]

Table III.

AVERAGE COMPOSITION OF VARIOUS FORAGES AND SILAGES.

	Water	Ash	Protein	Fiber	NFE	Fat
	%	%	%	%	%	%
Green soy bean (whole plant)	75.1	2.6	4.0	6.7	10.6	1.0
Green corn fodder	79.3	1.2	1.8	5.0	12.2	0.5
Soy bean hay (with pods and seeds)	11.3	7.2	15.4	22.3	38.6	5.2
Dry corn fodder (with ears)	42.2	2.7	4.5	14.3	34.7	1.6
Soy bean straw (after threshing)	10.1	5.8	4.6	40.4	37.7	1.7
Corn stover (plant without ears)	40.5	3.4	3.8	19.7	31.5	1.1
Soy bean silage	74.2	2.8	4.1	9.7	6.9	2.2
Corn silage	79.1	1.4	1.7	6.0	11.0	0.8
Clover silage	72.0	2.6	4.2	8.4	11.6	1.2
SB and Corn silage	76.0	2.4	2.5	7.2	11.1	0.8
SB & Millet silage	79.0	2.8	2.8	7.2	7.2	1.0

1. Farmer's Bulletin No.97.

In dairy cattle work the affect of different feeds and rations is reflected directly in the yield of milk and butterfat so that comparisons are relatively easily and accurately made. This feature makes the results secured in feeding soy beans to dairy cattle of considerable value.

In early work done by the Massachusetts Station, soy bean meal and cottonseed meal were compared for milk and butter production.[1] The station found that the soy bean ration produced a slightly larger quantity of milk and that the butter produced was of better quality but not quite as firm as that from the cottonseed meal-fed cows. They concluded that the soy bean meal was equal to, if not superior to, cottonseed meal for both butter and milk production. The Virginia Station says,[2] "---enough work has been done to indicate that three pounds of soy bean meal can be substituted for an equal amount of linseed meal with satisfactory results in feeding dairy cows." The Kansas Station found[3] that when soy beans made up one-half the grain ration for dairy cows, the butter became too soft to be satisfactorily worked after churning. This difficulty was not encountered when soy beans made up a small part of the ration, and as they are very rich, a small quantity is usually sufficient to furnish the nutrients required by the cow. They also calculated the value in money of various protein feeds based on the total nutrients contained and on the protein nutrients contained, and also the value of various hays based on the protein nutrients contained. The value of the concentrated feeds is figured with corn worth one dollar per 100

1. Massachusetts Annual Report 1893.
2. Virginia Bulletin No.168.
3. Kansas Bulletin No.125.

pounds and alfalfa hay worth twenty dollars per ton.

VALUE OF PROTEIN FEEDS.

	On a basis of total nutrients contained	On a basis of protein nutrients contained
Cottonseed meal	$ 2.80	$ 4.70
Soy bean meal	2.30	3.80
Linseed meal	2.20	3.70
Wheat middlings	1.20	1.60
Wheat bran	1.00	1.60
Wheat shorts	1.10	1.50
Skim milk	0.20	0.50

VALUE OF VARIOUS HAYS.

	On a basis of protein nutrients contained
Soy bean hay	$ 20.40
Cow pea hay	20.40
Red Clover hay	12.80
Mixed hay	11.20

The New Jersey Station says[1] that soy bean meal will take the place of cottonseed meal in a dairy ration, and it is undoubtedly superior aside from its food value because it has no deleterious effect upon the animal as does cottonseed meal which, if not fed judiciously, causes sonstipation and affects injuriously the general constitution of the animal. This station also says that soy bean stover produces milk at a lower cost than corn stover and that soy beans are profitable as a soiling crop for dairy cattle.

In an experiment conducted at the Tennessee Station,[2] three groups of cows in two lots per group were fed to compare (a) soy bean straw and corn stover, (b) soy bean hay and alfalfa hay and (c) soy bean meal and cottonseed meal. The results

1. New Jersey Circular No.21.
2. Tennessee Bulletin No.80.

obtained indicated that soy bean straw was very palatable and superior to corn stover as a feed. The soy bean ration produced 12 percent more milk and 14 percent more butterfat than did the corn stover ration. The soy bean hay and alfalfa hay were fed in combination with corn silage and corn and cob meal. At the end of the first 30 days of the trial, the results were in favor of the soy bean hay by 245 pounds of milk and 20.5 pounds of fat. The soy bean hay lot was then changed to alfalfa hay and the latter changed to soy bean hay for the next 30 days, when the lots were once more changed to their original rations. In both the second and third 30 day periods the soy bean hay proved a little superior to the alfalfa hay. The comparison of soy bean meal and cottonseed meal resulted in a slight superiority for the soy bean meal, as this lot yielded about 5 percent more milk and butterfat for the entire period than the cottonseed meal lot. In all three groups the rations and lots were interchanged so that the individuality of the animals would not affect the results.

The Massachusetts Station conducted an experiment to determine the effect of soy bean meal with a minimum percentage of oil, and of the oil,(a) upon the proportions of the several milk ingredients; (b) upon the chemical character of the milk fat; and (c) upon the consistency or body of the butter. They used two lots of six cows each, one lot of which received a normal grain ration consisting of feeds in the following proportions:- Wheat bran - 2 pounds; Ground oats - 3 pounds; Corn meal - 1.25 pounds; Gluten feed - 1.25 pounds; and cottonseed meal - 0.50 pounds. The cows were fed for 63 days, the first 14

being a preliminary period in which both lots got the normal grain ration, the second 28 days in which the Lot 2 cows got a soy bean meal ration of 2.3 pounds per head per day, and the last 21 days in which the Lot 2 cows got the normal grain ration plus 0.6 pounds of soy bean oil per haed per day. The conclusions drawn were as follows:-[1]

1. Soy bean meal seemed to be without influence in changing the proportions of the milk constituents or in imparting any flavor to the milk.
2. Soy bean oil was likewise without influence on the composition and flavor of the milk.
3. Soy bean meal didnot modify the chemical character of the fat, neither did it have any effect upon the separation of the fat from the milk serum, the time of ripening of the cream nor the thoroughness of the churning. Expert butter scorers could not detect any particular flavor in the butter as a result of feeding the meal. The meal imparted a notable softness to the body of the butter, but no sufficiently so as to injure its commercial value except during the warm weather.
4. The oil caused a marked softness of the butter; the latter also contained some 2 percent more moisture than did the butter produced by the normal ration. No other changes were observed.

In a two year experiment conducted at the Ohio Station[2] to compare soy bean hay with wheat bran and cottonseed meal as a

1. Massachusetts Annual Report 1908.
2. Ohio Bulletin No.267.

source of protein for dairy cows, two lots were fed as follows:-

Lot 1.	Lot 2.
Soy bean hay	Corn silage
Corn silage	Corn stover
Corn meal	Wheat bran
Cottonseed meal	Cottonseed meal
	Corn

In the second year the corn in Lot 2 was changed to corn meal but otherwise the rations were identical in both years' trials. The cows were fed for 121 days, 31 days preliminary feeding, 60 days on the trial proper and 30 days subsequently. The results of these trials were as follows:-

SOY BEAN HAY vs COTTONSEED MEAL AND BRAN.

	First year		Second year	
	Lot 1	Lot 2	Lot 1	Lot 2
	#	#	#	#
Dry matter per 100# milk	113.36	109.51	111.19	106.72
Dry matter per 100# fat	23.23	23.42	22.81	23.96

A similar trial comparing alfalfa hay with wheat bran and cottonseed meal showed the following:-

ALFALFA HAY vs COTTONSEED MEAL AND BRAN.

	Lot 1	Lot 2
Dry matter per 100# milk	105.3#	90.2#
Dry matter per 100# fat	24.0	20.7

The author makes the following comment:- "The above considerations show that alfalfa as well as soy bean hay can replace much of the high priced protein concentrates." Indeed in the first trial mentioned, soy bean hay made a very remarkable showing when compared with two protein concentrated feeds.

Three years of experimental work at the Missouri Station[1] brought out the fact that the factor determining the quality of soy bean silage is the amount of water present when the crop is put into the silo. Soy beans containing from 30 to 40 percent of dry matter kept well, showed no more loss of feeding

1. Missouri Bulletin No.162.

value than corn and made a very palatable silage for livestock. It also showed that although soy bean silage is higher in protein than corn silage, it is lower in carbohydrates and is therefore not far different in total feeding value.

The New Jersey Station found[1] that a ration of 36 pounds soy bean silage, 8 pounds alfalfa hay and 6 pounds corn meal produced more milk at a cost of 8.5 cents less per hundred than a ration in which the protein was largely supplied by wheat bran, dried grains and cottonseed meal. The latter ration was 36 pounds corn silage, 4 pounds wheat bran, 4 pounds dried grains, 2 pounds cottonseed meal and 6 pounds cornstalks.

The Wisconsin Station found[2] that a straight soy bean silage ration decreased the milk yield and flavored the milk and butter. However, they say, "The objections to soy bean silage which have been stated in the preceding would not, in our experience, apply to the mixed corn-soy bean silage."

A comparison of the amounts of protein, carbohydrates and fat produced on a acre each of soy beans and flint corn cut for green fodder, as determined by the New York Cornell Station[3], showed that the soy bean acre produced nearly 34 percent more of protein, while the acre of corn produced over 84 percent more of carbohydrates and fat than did the soy bean acre. Silage made from corn alone is known to be a wide ration and needs to be supplemented with foods richer than itself in protein in order to balance the ration. It is not to be inferred that a mixture of corn and soy beans as silage will make it unnecessary or unprof-

1. New Jersey Bulletin No.174.
2. Wisconsin Annual Report 1904.
3. New York Cornell Bulletin No.310.

itable to feed grain in the ration; but in practice it has been found possible to reduce the amount of grain fed to dairy cows and maintain the milk flow, if a portion of the silage is made up of soy beans.

SHEEP.

Even less work has been done with sheep than with dairy cattle towards determining the value of soy beans in the ration. What little there is, however, indicates that soy beans are of approximately the same value as cottonseed meal, just as they were in the case of beef cattle. The Purdue Station conducted experiments for three years[1] comparing the ground soy beans with cottonseed meal as a feed for fattening lambs. The rations fed were identical each year, shelled corn, oats, corn silage, clover hay and either ground soy beans or cottonseed meal. An average of the results of the three years' trials shows the following:-

SOY BEANS vs COTTONSEED MEAL.

	Lot 1. Soy beans.	Lot 2. Cottonseed meal.
Initial weight	57.4 #	57.1 #
Final weight	85.6	86.1
Total gain	28.2	29.0
Ave. daily gain	.272	.279
Feed per lb. gain		
Grain	3.93	3.91
Hay	3.44	3.39
Silage	4.92	4.87
Total	12.29	12.17

As in the results of comparing ground soy beans with cottonseed meal for beef cattle, we find very little difference in the above trials. In this instance also, we may safely assume that had soy bean meal been used, the lots fed it would perhaps have

1. Purdue Bulletins No.192, 202, 221.

proved better than the cottonseed meal-fed lots. But even as the results stand here, the practical equality of the home-grown supplement with the purchased feed makes it much more desirable as an economic method of feeding lambs.

Two trials at the Wisconsin Station[1] comparing soy beans with oats naturally showed the superiority of the legume. The lambs were fed equal parts of corn-soy beans and corn-oats together with a roughage of clover hay, corn stover or June grass hay. The average results of the two years' trials are:-

SOY BEANS vs OATS.

	Lot 1. Soy beans	Lot 2. Oats
Initial weight	107.9 #	107.6 #
Final weight	122.6	118.3
Total gain	14.7	10.7
Ave. weekly gain	1.23	0.89
Feed per lb. gain		
Grain	6.23	8.95
Roughage	8.81	12.32
Total	15.04	21.27

These lambs were being grown out to be kept in the breeding flock and not being fattened for market. The authors comment as follows:- "The results of these two trials show that soy beans are an economical supplement to corn for gains with sheep both in body weight and in wool production." This last refers to the fact that the soy bean-fed lot in the second experiment produced the heavier clip of wool.

POULTRY.

Experimental work with soy beans for poultry is practically non-existant, only two very recent reports being available. In the first[2], 14 lots of 15 chickens each were used. All were

1. Wisconsin Annual Reports 1904 & 1905.
2. Jour. Agrl. Research - V.XVIII - p.391.

given a basal ration as follows:-

Ground corn	50 parts by weight
Corn meal	35 parts by weight
Corn bran	15 parts by weight
Ash	3 parts by weight
Charcoal	3 parts by weight

The 14 lots were divided into three groups of four each, the two extra groups being checks. The necessary crude protein was provided by meat scrap, soy bean meal and a combination of these two feeds as follows:-

Lot	Parts meat scrap	Lot	Parts soy bean meal	Lot	Parts meat scrap and soy bean meal
1	5	5	5	9	5
2	10	6	10	10	10
3	15	7	15	11	15
4	20	8	20	12	20

Lot 6, fed 10 parts of soy bean meal by weight, gave the best results followed in order by Lots 10,11,12,7,9,8 and 5. The lots fed meat scrap alone gave the poorest results, their order being Lots 4,1,2 with Lot 3 giving the poorest result of any. As meat scrap is regarded as a very good source of protein for poultry, we may judge from these results that soy bean meal compares very favorably with it to say the least. The authors make the following comment:- "The data which have been presented tend to show that ckicks are capable of greater utilization of soy bean meal protein than are mammals, with which nearly all previous nutritional work has been done."

In the other poultry trial[1], three lots of chickens were fed as follows:-

Lot 1.		Lot 2.		Lot 3.	
Corn meal	31.2%	Corn meal	40 %	Corn meal	32.4%
Soy bean meal	7.6	Buttermilk	60	Soy bean meal	7.6
Salts	1.2			Water	60.0
Water	60.0				

1. Jour.Physiol.V.LIX -p.298

The results of this trial were as follows:-

Lot	Gain in 12 days	Feed per gram gain	Relative value
1	255 gms.	3.25 gms.	100.00
2.	268 "	3.41 "	95.31
3.	168 "	4.74 "	68.57

The authors state that these figures are the average of the results secured from three trials. Here again we find soy bean meal compared to an almost ideal supplement, buttermilk, and in this instance it not only compares favorably with the milk but proves to be slightly superior.

These two feeding trials with poultry serve to show that we have a great deal to learn about the value of soy beans for chickens and that if further experiments are conducted we may have reason to change some of our beliefs about what is the best protein feed for poultry.

HORSES.

No feeding trials involving the use of soy beans for horses are available so that nothing definite can be stated as to their value. Conversation with horse breeders and experiment station workers brings forth no definite figures but it indicates that soy bean hay, whenever it has been used, has proved very satisfactory compared to alfalfa hay. Nothing is known as to the value of soy bean meal as a protein concentrate for horses. This field of investigation is as yet wholly untouched and offers many opportunities for original research.

PART III.

I. THE MANUFACTURE OF SOY BEAN OIL.

The Chinese have been accustomed to use vegetable oils as a source of food and light since early times. The soy bean has been their principal source of oil and the expression of this oil has been of necessity carried on almost everywhere to meet local needs. Until very recently, the method of extracting the oil has been very primitive, and still is for that matter in the more or less isolated parts of the country. At the close of the Sino-Japanese war, an English firm, believing that there was a future in the soy bean oil industry, installed a steam-driven bean crusher and a mechanical expressor in their Manchurian mill. This was the first mechanical device used in the Orient for producing soy bean oil. At the close of the Russo-Japanese war, a Japanese firm built a mill at Yingkou in which hydraulic pressure was used to express the oil.

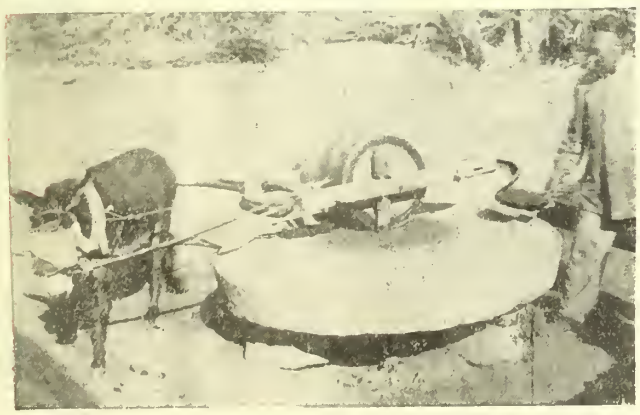
In 1906, the first bean mill to operate in Dairen, (Dalny), Manchuria began production. Since that time the development of the export trade has made Dairen the leading port for the shipment of beans and oil. In 1919, there were 60 mills in and around the city and in both bean cake and bean oil the port of Dairen contributed more than 55 percent of the whole output of Manchuria. In 1919, there were in Manchuria 310 mills producing annually a total of 55,169,000 pieces of bean cake, (a piece of cake weighs about 61 pounds), in addition to 32,390,000 kin of bean meal and 256,989,000 kin of bean oil.*

* A kin equals 1.33 pounds.
Production of bean cake 193,000 tons.
Production of bean meal 21,593 tons.
Production of bean oil 171,328 tons.

The oil manufacturing methods may be classified into two kinds, viz., the expression method and the extraction system. However, only one mill in Manchuria uses the latter. In the expression method, there are three processes used, beginning with what is generally known as the wedge method or the old-fashioned, primitive process; second, a jack-screw press operated by hand; and third, the modern hydraulic pressure system. There are two methods of crushing the beans in use in Manchuria today. One which makes use of a steam-operated crusher, and the other in which a donkey is used to pull around a huge, cumbersome granite wheel. The latter is the native means of crushing beans.

No matter whether the donkey and the wedge are used in producing the oil or the steam crusher and the hydraulic press, there are four essential steps which must be followed. They are, crushing, steaming, preparing for the press, and pressing. A description of the native or primitive processes will be interesting and by imagining the use of the steam crusher for the donkey and the hydraulic press for the wedge, we can get an accurate description of the modern methods. The preparation for the press is the same in both the native and the modern processes.

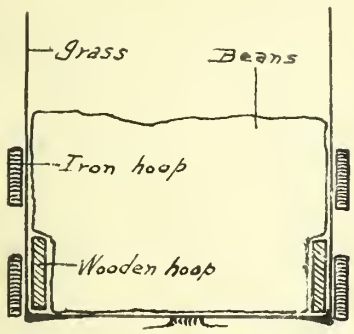
The native mill consists of a massive granite grindstone or wheel resting upon a circular platform enclosed by a low wall. In the center of the platform is a wooden upright, around which the stone is revolved by mule power. The beans are fed onto the



platform in front of the wheel and an iron blade,so arranged as to sweep the crushed beans from the platform into a shallow trough around the edge follows after.

Next comes the steaming process. The beans, crushed into thin wafers about the size of a dime, are taken from the trough, placed in a gunny-sack and laid on a wooden grating over a large pot of boiling water. They are steamed thus for about 15 minutes and then removed and prepared for pressing. The modern method os steaming differs slightly in that the beans are steamed under about 30 pounds pressure for from one to two minutes.

In preparing the steamed beans for the press, the workman takes a bunch of long, wide-stemmed, coarse grass tied together at the bottom and spreads it out into a fan shape. Another bundle is placed opposite the first and both are placed inside two iron hoops. A wooden hoop is forced down inside the grass and the iron hoops thus causing the free ends of the grass to project vertically over the edges of the hoops. The beans are then dumped in, the wooden hoop removed, the loose ends of the grass turned in over the beans and the cake is ready for pressing.



The capacity of the ordinary native mill is five of these cakes, while the hydraulic press handles as many as 100 at a time. The cakes are placed in the native press consisting of four massive upright beams bound together with iron and so arr-

anged that when horizontal logs and wedges are driven into place by mallets, the bundles are compressed and the oil expressed. When the edges of the iron hoops surrounding the bundles are forced together, the oil is considered to be wholly extracted and the bundles are allowed to remain in the press while the next batch is being prepared.

Naturally, a large percentage of oil still remains in the beans pressed by such crude appliances as these. The hydraulic press exerts a pressure of about 50 tons per square inch for the first 10 minutes, when the pressure is increased to 130 tons per square inch and the beans allowed to stand for two hours.

The extraction method is the most advanced way of removing the oil from the beans. In this method a solvent of volatile nature, commonly benzine, is used. Ordinarily a battery of four extractors is used, through which the solvent is kept in circulation in such a manner that the nearer the beans are towards complete extraction of the oil, the fresher will be the solvent. After all the oil possible has been dissolved, the fatty solvent is removed to storage tanks and the remaining meal dried by steam heat. The solvent next goes to the evaporating kettle where the benzine is evaporated and distilled for use once again. The remaining soy bean oil is placed in large tanks and allowed to settle thoroughly so that any impurities drop to the bottom before being placed on the market. The loss of the solvent from one extracting process is nominal, only about one percent of the original amount being lost.

The above description of the modern pressure and

extraction systems in the Orient will serve for American methods as well because there are very few differences, and these only in minor points. The majority of American mills use the pressure or expression system, although the extraction method is becoming more common because of the greater amount of oil it removes. The average pressure mill leaves from 5 to 8 percent oil in the meal while the extraction method removes all but 2.5 to 3 percent.

The soy bean cake coming from the hydraulic press is in the form of large discs about 24 inches in diameter and 3.5 inches thick, weighing in the neighborhood of 61 pounds. Before being used as a feed, these cakes must be again run through a crusher or pulverizer and reduced to the form of meal. If the meal is to be used for human food, another pulverizing is necessary to convert it into finely ground flour. The extraction method, of course, leaves the soy beans in the form of a rather coarse meal which is suitable for use as a stock feed or as a fertilizer.

The modern linseed oil mill or cottonseed oil mill in the United States does not need to make any very extensive changes in its equipment to be able to crush soy beans. The methods of crushing all three types of seed are very similar in character. About 1600 to 1700 pounds of soy bean meal and about 260 to 350 pounds of oil are obtained from each ton of soy beans crushed, the remaining amount representing chiefly loss by cleaning and evaporation.

II. PRODUCTION AND IMPORTS IN THE UNITED STATES.

Figures on the production of soy bean oil in the United States are not extensive but they indicate that the industry is undergoing a very vigorous development. An increase of over 800 percent in three years is really little short of astounding. The growing demand for the oil, the increasing use of soy bean meal as a stock feed and a considerable increase in the acreage devoted to soy beans have all helped to bring about the increase in oil production. The figures on oil production are as follows:-

PRODUCTION OF SOY BEAN OIL.[1]

1916	9,920,000	pounds
1917	42,074,000	pounds
1918	79,861,000	pounds

There has also been a considerable increase in the acreage devoted to growing soy beans during the past few years. The steadily growing demand for beans to convert into oil, the increasing use of the soy bean as a stock feed, the high prices obtainable for seed beans and an increasing appreciation of the value of the crop to farm lands have all contributed to the bringing about of a 23 percent increase in soy bean acreage since 1917. Figures of the United States Department of Agriculture show this:- [2]

SOY BEAN ACREAGE, PRODUCTION AND VALUE.

Year	Acreage	Ave. yield per acre	Production	Farm price per bu. Nov. 15th	Farm value
1917	154,000	14.8 bu.	2,283,000 bu.	$ 2.86	$6,529,000
1918	169,000	17.7	2,997,000	3.20	9,590,000
1919	175,000	14.1	2,460,000	3.47	8,530,000
1920	190,000	15.8	3,002,000	3.06	9,199,000

1. Statistical Abstract of the U.S. 1920.
2. U.S.Department of Agriculture Year Book 1920.

It seems very probable that the peak price for soy beans on the farm was reached in 1919. The constantly increasing acreage and, when better cultivation methods prevail, increasing average yields will so enlarge the ouput that the price will drop to more reasonable levels. In connection with the production of soy beans in the United States, we find that certain regions differ in regard to their ability to produce soy beans with large percentages of oil. The map on page 78 shows the locations of these different regions.

KEY TO MAP

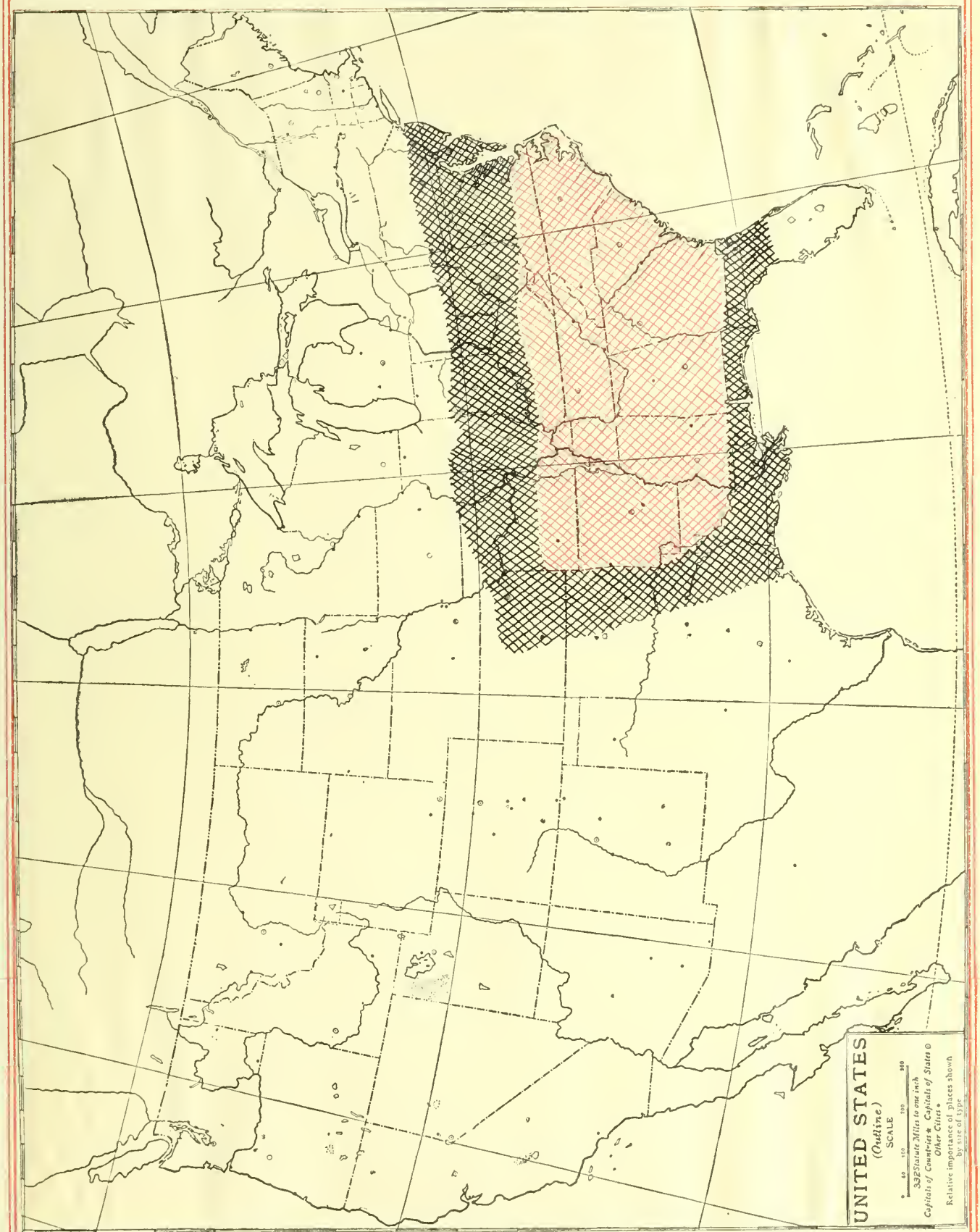
Region best suited to the production of soy bean varieties yielding a large percentage of oil.

Varieties produced in this region donot produce such large amounts of oil.

Notwithstanding the increasing production of both beans and oil in the United States, the imports of soy beans and soy bean products have steadily increased during recent years. The import figures of the United States Department of Commerce show the steadily increasing volume of soy bean and soy bean product importations.[1]

(See page 79)

1. Statistics of Imports and Duties-1908-1918. United States Tariff Commission. 1920.



Adapted from U.S.D.A. Bulletin No. 439.

TABLE IV.

QUANTITY AND VALUE OF SOY BEANS, SOY BEAN CAKE AND SOY BEAN OIL IMPORTED INTO THE UNITED STATES, 1910 - 1918.

Year	Soy Beans		Soy Bean Cake		Soy Bean Oil	
	Quantity #	Value $	Quantity #	Value $	Quantity #	Value $
1910						1,019,842
1911			2,115,422*	59,626	41,105,920	2,555,707
1912			2,416,052*	64,350	28,019,560	1,576,968
1913			7,004,803	93,002	12,440,406	635,882
1914	1,929,435	49,507	3,163,260	38,255	16,363,645	830,870
1915	3,837,865	87,306	5,975,592	64,307	19,210,028	901,643
1916	3,003,065	78,963	10,468,001	103,081	98,171,275	5,131,582
1917	5,344,334	132,572	11,760,935	136,064	162,734,010	11,410,606
1918	31,812,997	692,964	586,820	9,964	336,899,646	32,836,134

* Includes bean cake or bean stick, miso or similar products.

III. USES OF THE SOY BEAN AND ITS PRODUCTS.

It is very probable that no other plant offers itself to so wide a variety of uses as does the soy bean. The accompanying list shows the classification of uses to which the plant is put. This list has increased in extent considerably of recent years with improved methods of manufacturing the oil and with the development of new uses by industrial chemists.

TABLE V.

USES OF SOY BEAN PLANTS AND SEEDS.[1]

- Plants
  - Green manure
  - Forage
    - Hay
    - Ensilage
    - Soiling
  - Pasture
- Seeds
  - Meal
    - Human food
      - Breakfast foods
      - Diabetic foods
      - Flour
      - Infant foods
      - Macaroni
      - Crackers
      - Milk
    - Stock feed
    - Fertilizer
  - Oil
    - Glycerin
    - Explosives
    - Enamels
    - Varnish
    - Waterproof goods
    - Food products
      - Butter substitutes
      - Lard substitutes
      - Edible oils
      - Salad oils
    - Linoleum
    - Paints
    - Celluloid
    - Soap stocks
      - Soft soaps
      - Hard soaps
    - Rubber substitutes
    - Printing inks
    - Lighting
    - Lubricating
  - Food products
    - Dried beans
      - Coffee substitutes
      - Soy sauce
      - Roasted beans
      - Boiled beans
      - Baked beans
      - Soups
      - Vegetable milk
        - Cheese
          - Fermented
          - Smoked
          - Fresh
          - Dried
        - Casein
        - Condensed milk
        - Fresh milk
        - Confections
      - Breakfast foods
    - Green beans
      - Green vegetables
      - Canned vegetables
      - Salads

1. Far. Bul. 973

Leaving the discussion of the soy bean for human food until later, we find that in the Orient the uses of the plant and its products are very numerous. The bean refuse is used as a fertilizer and as a feed for hogs; bean oil is used, where not superseded by kerosene, as an illuminant; it is also used as a substitute for lard in cooking by the poorer classes; as a lubricant, it is used for greasing axles and parts of native machinery; and some of its other uses, in South China particularly, are in making waterproof cloth, paper umbrellas, lanterns, for mixing with lacquer in varnish making, and for making printing inks. The bean cake has two principal uses in Eastern Asia. For centuries it has been used as a fertilizer on the sugar plantations and as a feed, it is used in Manchuria for horses and mules, but only when very hard work is being done, and then it is mixed with bran and kaoliang stalks. It is also used somewhat as a fattener for stock.

One of the principal uses of bean oil in both the United States and Europe is in the manufacture of soft soap, as it can be made use of in its crude state for this purpose. The oil consists mainly of the glycerides of palmytic, oleic and linolic acids. Recent secret processes are now claimed to be in operation in this country whereby the soy bean oil can be used in making the best grades of hard soap.

The soy bean oil is classed as a semi-drying oil. It is of lighter color than linseed oil and may be made still lighter by refining. Soy bean oil mixtures are excellent for the grinding of certain paste tinting colors. The oil grinds easily

with pigments and produces pastes that remain soft and less liable to stiffening in the package than those made with pure linseed oil. Exposure tests show that 20 percent of soy bean oil mixed with 80 percent of raw linseed oil will produce a paint liquid that wears as well as one using only linseed oil. Because of the above properties of soy bean oil, it would appear that it is even more desirable than straight linseed oil for color grinding and that colors produced with it should really have a higher sales value than those ground wholly in linseed oil.

Soy bean oil has a higher flash point than any other vegetable oil used in the paint industry. It may be heat treated and blown to a viscous form. It requires a higher percentage of drier than linseed oil, and in this connection it has been found that cobalt driers are very satisfactory and more efficient than lead or manganese driers.

New uses seem to be appearing constantly for soy bean oil. Manufacturers of linoleum, varnishes, explosives, greases and oils, and other more or less related lines are experimenting continuously in endeavoring to make still further use of the oil. There is a vital reason in back of all this research work as letters from officials of various commercial firms will show. The fact that the annual production of flax seed is decreasing steadily has caused the linseed oil mills throughout the country to cast about for other sources of raw materials. The soy bean oil is readily adaptable to many uses now largely monopolized by linseed oil and the linseed oil mills may be easily converted into soy bean oil mills. Furthermore, the demand for soy bean oil

is increasing and the production of the soy bean is hardly keeping pace with the demand.

The William O. Goodrich Co., proprietor of the Milwaukee Linseed Oil Works says, "In view of the fact that the farmer is growing flax seed less and less each year, and with the millions of dollars invested in plant equipment for the production of linseed oil, which will become a poor investment, we are desirous of creating if possible a new industry that will take the place of our own, or at least help utilize the facilities which we have. It requires very little change in the process of crushing soy beans with linseed equipment, and you may rest assured that we are especially interested in this subject."

The Hirst & Begley Linseed Works, Chicago, say,- "We are naturally interested in this matter (soy beans) and if the crop was large enough I dont think there is any doubt but we would be willing to so adjust the machinery of our plant to make practical tests and possibly if the right encouragement was afforded to continue it as an industry.---- It seems to me that there is a big field for development work in this direction. The oil has a great deal of merit and as you know is in big demand."

The Stevens Grease & Oil Co., Chicago, says,- "The only object in using corn oil or linseed oil in place of soya bean is due to the price being lower. It is immaterial to us which of the three grades we use as they will all answer our purpose; the price being an object. (We) assure you that if the soya bean is raised and crushed, we will be in the market for oil at all times."

The Lewis-Simas-Jones Co., Importers, of San Fransisco, says,- "---if we could get soya bean cake or meal at a price that would meet the competition from Manchuria, we could no doubt handle a considerable quantity."

The Nairn Linoleum Co., Kearney, N.J., says,- "---it is possible for the Linoleum industry, like the paint industry, to use considerable quantities of soy bean oil."

The Staley Co. of Decatur, Ill. is installing a mill for grinding soy beans and an oil plant for mechanically extracting the oil from the bean. This plant will be ready in the Fall of 1922 and will have a capacity of 200 tons of beans every 24 hours. Mr. Staley, President of the company says,- "The variety, or varieties, of beans containing the highest or greatest volume of oil will be the most desirable for the farmer to produce, and will bring the highest price in the market, because the price paid for the beans will vary according to the oil content."

These letters from commercial firms indicate the general attitude towards the soy bean. They are ready and willing to procede with the development of the industry and the use of the oil. Up to date, however, the high prices they have been obliged to pay for soy beans has acted as a deterrant. However, the linseed oil companies in particular see the "handwriting on the wall" and will make strenuous efforts to keep themselves in business through the aid of the soy bean industry.

IV. SOY BEANS AS HUMAN FOOD.

Once more we must go to the Orient if we wish to find the origin of the use of soy beans as human food. In China and Japan, soy beans and soy bean products rank second only to rice in importance as a food. The high protein content makes for a well-balanced ration when the soy bean is eaten with the staple food stuff of the Orient, rice. Through centuries of use, the Chinese and Japanese have elaborated the preparation and use of soy beans until they have a great variety of products.

Among the more important of these soy bean foods are, first, To-fu or bean curd which is the coagulated vegatable casein of the beans, and its various by-products such as To-fu kan-tzu or dry bean curd cakes, To-fu nao or curd brain, To-fu p'i or curd skin, Ch'ien-chang to-fu or wafers and Tung to-fu or frozen curd; next, Chiang or the Chinese paste eaten with fish, meat and vegetables; third, soy bean milk and a cheese made from it; fourth, boiled and baked beans in various forms and bean sprouts; fifth, natto, miso, and similar products; and finally, Shoyu or soy sauce. This last is the only preparation that has been introduced to any extent in this country. It is the common table relish in "Chop Suey" restaurants. In odor and taste it somewhat resembles a good quality of meat extract, although it is perhaps more salty. The manufacture of this sauce is conducted on quite a large scale in China and Japan, the annual output in Japan being about 2,000,000 barrels.

The composition of some of these various Oriental food stuffs gives us some idea as to their value.[1]

1. Farmer's Bulletin No. 121.

TABLE VI.

COMPOSITION OF ORIENTAL FOOD PRODUCTS

FROM SOY BEANS.

Product	Water	Protein	Fat	N.F.E.	Fiber	Ash
	%	%	%	%	%	%
Fresh to-fu	89.00	5.00	3.40	2.10	* *	0.50
Natto	15.32	41.42	23.65	15.05	1.48	3.08
White miso	50.70	5.70	24.40		8.25	12.50
Red miso	50.40	10.08	18.77		12.60	6.60
Swiss miso	12.53	26.43	13.91	19.54	1.41	26.18
Shoyu	63.29	8.31	* *	5.10	* *	19.45

Soy bean flour is used to only a very slight extent in China and Japan.

In Europe and America, the consumption of soy beans as a food stuff is small proportionately to their other uses. Experiments have been made in blending soy bean flour with wheat flour and corn meal. It has been found that about one-quarter soy bean and three-quaters wheat flours give the best results, and about one-sixth soy bean flour with five-sixths corn meal is best for muffins, etc. When thus blended, the soy bean flour imparts a pleasant flavor and gives a considerable increase in food value. The following table shows the composition of some of the various flours:[1]

TABLE VII.

COMPOSITION OF VARIOUS FLOURS.

Flour or meal	Water	Ash	Fat	Fiber	Protein	Carbo-hydrates
	%	%	%	%	%	%
Soy bean*	6.14	5.24	20.71	1.72	39.56	26.63
Soy bean**	6.10	6.20	4.50	2.05	47.30	33.85
Wheat	12.00	0.45	1.00	0.20	11.00	75.35
Corn meal	10.00	0.90	2.70	0.80	8.50	77.10
Rye	9.00	1.10	1.50	0.65	12.00	75.85
Graham	9.60	1.80	2.20	1.90	12.60	71.90
Whole wheat	10.90	1.05	2.00	1.00	12.00	73.05

* From whole bean.
** From soy bean cake.

1. U.S.D.A. Bulletin No.439.

There has been placed on the English market a so-called "soya flour" which is 25 percent soy bean and 75 percent wheat. It is being used to make a very palatable soy bread which may be purchased from bakers in England. A very similar bread has been on the market in Amsterdam for about 30 years. This soya flour is also being used to make biscuits in England which already constitute an article of export.

In the United States, soy bean flour has been used principally by certain companies manufacturing patented, special foods such as so-called "diabetic" flours, breads, biscuits, etc. The Jireh Food Co., Morris Plains, N.J. is one. They say,- " We have been manufacturing soy bean flour for the use of diabetics for many years----we are interested in a starchless variety only and of this variety (selected Yellow Mammoth) we are using a certain quantity." Another such company is The Cereo Co., Tappan, N. Y., which says,- "We have experimented with soy beans as a human food for a number of years and believe that in time they will come into general use, that is, will be used daily by all classes of the population. (We) expect to feature their use from now on."

There is one disadvantage in soy bean flour. It cannot be bleached and therefore is not suited for use commercially in white bread, at least not at present, nor until the consumer has been thoroughly educated and informed as to the different appearance of the bread.

Soy bean milk has only recently come to have any value in America. Because of its food value and for sanitary reasons

it is said to be very valuable for cooking purposes and for use by bakers and by manufacturers of chocolate and candy. Unfortunately, it is not very palatable.

Soy bean oil for human food seems so far to be confined to use in butter and lard substitutes and in salad oils, where it is usually mixed with an oil of animal origin to conceal its very slight odor. It is of good color and is rather palatable. It has been studied by various Home Economics departments throughout the country and been found to compare very favorably with the more common table oils in digestibility. It seems probable that soy bean oil may eventually be used in almost any line of food manufacture where vegetable oils are now used, because of the rapid improvements being made in the process of refining the crude oil.

Other miscellaneous uses to which soy beans are put for human food are, first, boiled just as are our own navy or field beans; second, baked by mixing one-third navy and two-thirds soy beans; third, roasted properly, they make a very good coffee substitute being as palatable as the cereal preparations now on the market; and finally, when about three-fourths developed, the green beans may be used as are lima or green beans.

V. PLAN FOR A CO-OPERATIVE SOY BEAN MILL.

On page 44 of this paper the statement was made that a plan would be suggested later whereby the farmer would be enabled to secure his soy bean meal at a very low cost from soy beans produced on his own land. It is proposed that the remaining space be occupied in briefly outlining a plan for a co-operative soy bean mill.

This seems to be an age of co-operation. The entire world knows of the success of various non-profit organizations of producers banded together for the common good. A few of the more prominent of these are the co-operative creameries of Denmark, the co-operative orange and lemon growers of California, the co-operative livestock producers of the Central West and the co-operative fruit growers of the South. These associations are all live, going concerns. They have all succeeded in their respective fields. Why should a co-operatively operated soy bean mill not do likewise?

As matters stand at present, the farmer who sells his soy beans to a privately owned mill and buys his soy bean meal at market prices is the loser both ways. He gets less for his beans than if he had sold them for seed and he pays for the cost of converting those beans into meal plus a profit for the manufacturer. In a co-operative soy bean mill association this would not happen. The business, being operated upon a strictly non-profit basis for any individual would very materially reduce the cost of soy bean meal.

Let us suppose that a farmer has a forty acre field of

soy beans averaging 20 bushels to the acre. This is a total of 800 bushels of beans, which at 60 pounds to the bushel is 24 tons. The average yield of oil and meal being about 300 pounds and 1650 pounds respectively from a ton of beans, means that about 7200 pounds of oil and 39,600 pounds of meal would be produced from the forty acres.

The oil is of no use to the farmer in its crude state, and there is a steady and increasing demand for it at good prices. Therefore, the oil can easily be disposed of to any one of a number of paint, explosives, linoleum, food products, grease or soap manufacturers. While it is impossible to state here definitely the ratio between the cost of manufacturing the oil and meal and the price received for the oil, it is fairly certain that with good management the price received for the oil would go a long way towards paying for the cost of manufacturing both oil and meal.

Returning to the 40 tons of soy bean meal produced, as a by-product from the manufacture of the oil, let us see what it will do. First, if the farmer feeds cattle it will supply all the protein concentrates necessary for 100 steers for 100 days, feeding them an average of 4 pounds per head per day. Second, if he raises hogs it will supply an excellent protein supplement to corn for 250 hogs for almost a year at an average of 0.5 pounds per head per day. Lastly, if he feeds no livestock in sufficient numbers to use the meal, it will sell to some other farmer who does need it.

All such sales of meal and oil to persons not members of the mill association would of course be at prevailing market

prices, but to members the meal would sell for cost of manufacture. The usual practice in co-operative producer's associations is to charge the members a fixed price per given unit of product handled sufficient to cover all expenses. At the close of the fiscal year, when the accounts are balanced and the surplus determined, each member is returned his proper share based upon the amount of product the association has handled for him. In this way the members are assured that they receive for their goods the best average price less a minimum expense for marketing. In a soy bean mill, similar methods could be used with provision made for debiting the member's account with the cost of all soy bean meal returned to him. All expenses of operation would be borne by members in proportion to the tonnage of beans they sent to the mill and likewise, all surplus would be shared on a similar basis. In this connection it should be provided in the constitution or by-laws that no person, not a producer of soy beans, be granted membership in the association.

The details of incorporation, membership, management, operation, etc. cannot of course be gone into here, but there are plenty of successful co-operative organizations now in operation whose constitutions and by-laws would serve, with modifications, as models for a co-operative soy bean oil mill association. It is entirely possible for such a mill, honestly managed and dealing fairly with farmer and buyer of oil and meal, to build up a successful business and to return to its owners a good interest on their investments besides supplying them with soy bean meal at cost.

It is to be hoped that some such organization will be formed somewhere in the Corn Belt in the near future so that farmers engaged in producing and feeding livestock will be relieved of the burden of high prices for commercial concentrated feeds and thus assisted in producing market animals at a profit.

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